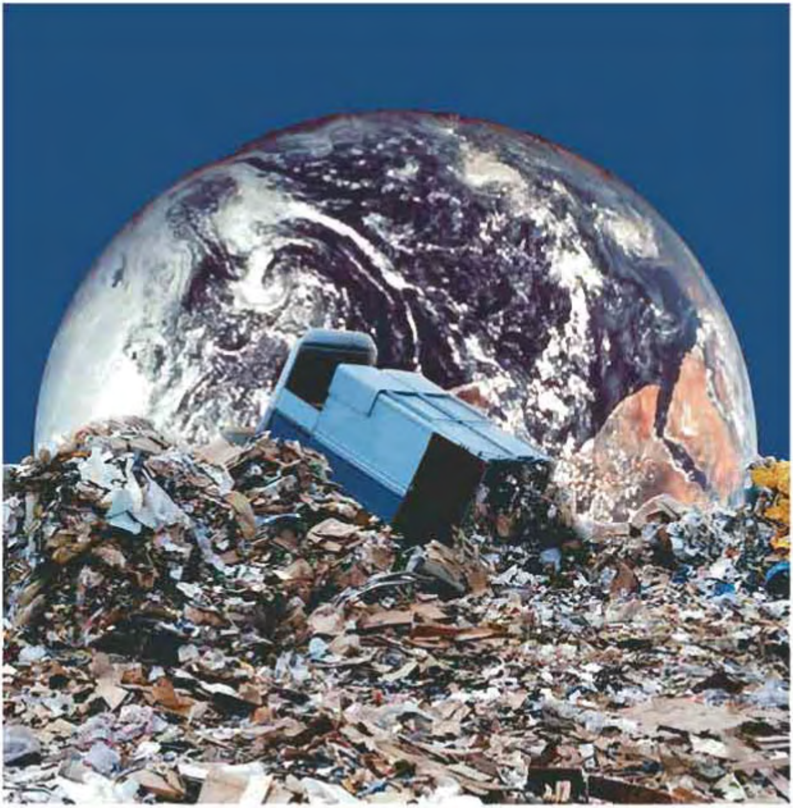

POLLUTION A to Z

pol • lu • tion [illegible] 1. The act or process of polluting or the state of being polluted. 2. The contamination of soil, water, or the atmosphere by the discharge of harmful substances.

POLLUTION A to Z

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pol • lu • tion (pə-lo͞o′ shən) *n.* 1. The act or process of polluting or the state of being polluted. 2. The contamination of soil, water, or the atmosphere by the discharge of harmful substances.

Richard M. Stapleton,
Editor in Chief

volume 1

Abatement to ISO 14001

Index

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Pollution A to Z
Richard M. Stapleton, Editor in Chief
Patricia Hemminger, Ph.D., Associate Editor
Susan L. Senecah, Ph.D., Associate Editor

For more information, contact
Macmillan Reference USA
300 Park Avenue South, 9th Floor
New York, NY 10010

Or you can visit our Internet site at
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Preface

Can you see the Great Milky Way where you live? Most Americans cannot. The greatest vista known to humankind is obscured by the veil of light pollution that shrouds all but the least developed regions on Earth.

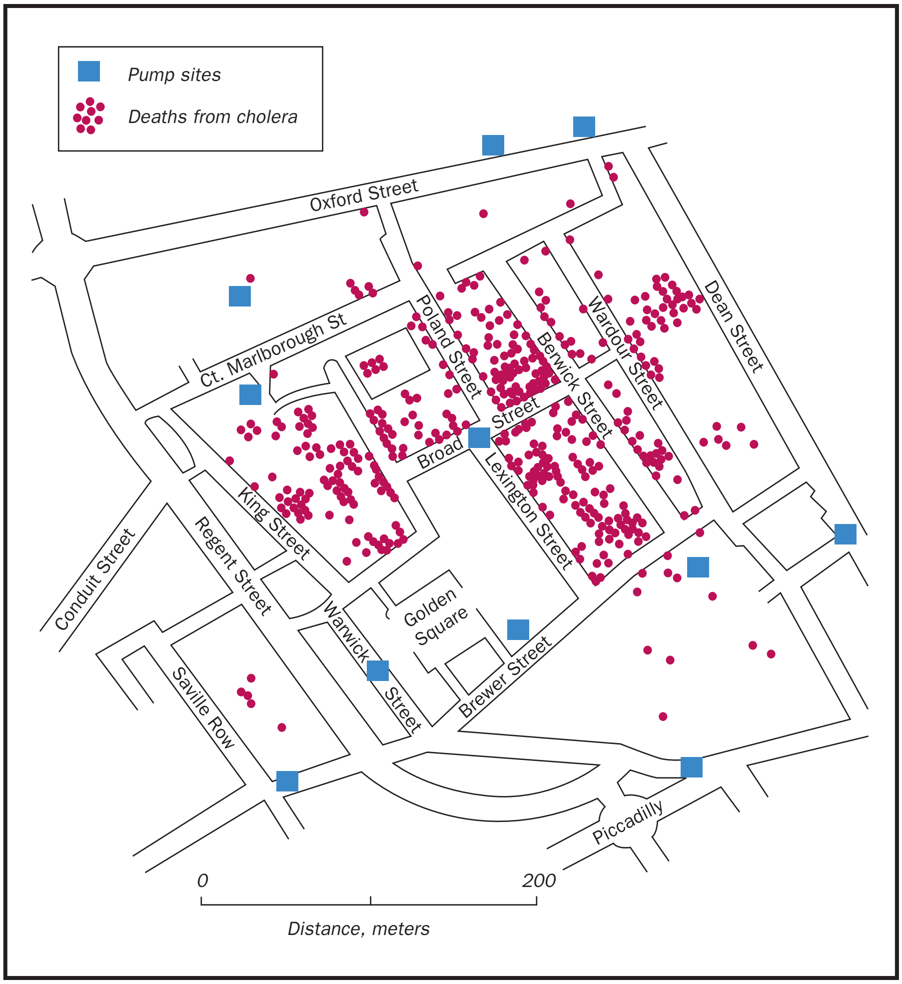
From the quality of life to life itself, there is not one person who is not affected in some way by pollution. Pollution affects our ability to swim in local waters or enjoy clear views in our national parks. More critically, pollution is responsible for waterborne diseases, birth defects, increased cancer incidence, and neurological problems ranging from loss of intelligence to madness itself. Pollution can kill instantly—over 8,000 died in just three days when methyl isocynate leaked from the Union Carbide facility in Bhopal, India—or it can take decades for the full impact to be known. Indeed, the number of lives cut short by the radiation released when the Chernobyl nuclear reactor exploded in the Ukraine in 1986 is still being counted.

The other fundamental truth about pollution is that we have no one to blame for it but ourselves. Yes, there are natural causes of pollution, and we include an article on *Natural Disasters*, but the preponderance of pollutant threats are anthropogenic—caused by man. From lead in paint to mercury in water, PCBs in rivers to VOCs in the atmosphere, from CFCs to greenhouse gases, the sources of pollution can be traced to the decisions of industry, government and, ultimately, the individual consumer/voter.

With that in mind, one entry deserves special mention. *Lifestyle* is less an article than an opinion essay. Its inclusion is meant to challenge the reader's social choices, to ask you to consider how your own personal lifestyle affects the environment. Do you use bottled ketchup or individual packets? Do you ride to school in an SUV or take a bus? The fact is that just as every person on the planet is affected by pollution, so each of us directly and indirectly creates pollution. Some of us just create more of it than others.

One caution: if you are looking to these volumes for the answers to all questions about pollution and its effects on human and environmental health, you will be disappointed. There are dozens—perhaps hundreds—of toxic substances, for example, for which we do not have health-based standards, meaning we do not know what is a "safe" level of exposure. And if we know little about these contaminants individually, we know virtually nothing about the cumulative (synergistic) impact of multi-contaminant exposure. Perhaps the most important thing we have learned in the last half-century is how little

A map of London, England, showing locations of pumps and deaths from cholera during the epidemic, 1854. See Health, Human; Snow, John; Water Treatment.



we know. There is no shortage of discovery left for the next generation to undertake.

Organization of the Material

As its title would suggest, *Pollution A to Z* is organized alphabetically with 264 articles presented in two volumes. Articles are cross-referenced. Authors were aware of (and sometimes wrote) related articles and, for the fullest understanding, the reader is encouraged to explore at least one level beyond the subject first selected. This is made easier with the inclusion of cross-references at the end of many articles. You will find that articles are balanced between hard science and social science. You can research the contaminants that pollute a river, learn the health impacts of the pollution, and then trace society's response, from activism through the political process required to enact legislation to the enforcement that ultimately slows or reverses the pollution.

Each entry has been commissioned especially for this work. Our contributors are drawn primarily from the ranks of academia and government, each chosen for his or her particular experience and expertise. Who better, for instance, to write about the first Earth Day than Denis Hayes, the man who organized it. Equally important, our authors were chosen for having the

Clean-up efforts underway at Love Canal, May 22, 1980. See Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Environmental Movement; Gibbs, Lois; History; Laws and Regulations, United States; Mass Media; Politics. (©Bettmann/Corbis. Reproduced by permission.)

uncommon ability to make their knowledge accessible to advanced high school students and university undergraduates. We also provide a glossary in the back matter of each volume, summarizing the definitions of the terms in the margins throughout the set.

The two volumes are richly illustrated with charts, tables, maps, and line drawings. Each, along with the many photographs, was selected to amplify the text it accompanies. Historic photographs such as the one taken at noon during Donora, Pennsylvania's, killer smog are especially important; they convey far more about the state of our environment at its nadir than any words could. Finally, articles include selected lists of additional resources. The lists focus on materials that students can reasonably expect to locate, and each contains at least one Internet reference.

Acknowledgements

There are so many people to thank for their commitment, encouragement, and patience along the way. First, the editorial team at Macmillan Reference

Boats approaching the oil-covered beach of Green Island, Alaska, following the 1989 *Exxon Valdez* oil spill. See Disasters: Chemical Accidents and Spills; Disasters: Oil Spills; History; Industry; Mass Media; Petroleum. (©Natalie Fobes/Corbis. Reproduced by permission.)

USA and the Gale Group. In particular, my thanks to Hélène Potter for her unflinching support, and to Marie-Claire Antoine, Michael J. McGandy, Shawn Corridor, Patti Brecht, and Frank Castronova. Their gracious patience, from the initial vision through searching for just the right authors to the endless tweaking of content, has been a much-appreciated constant. No one, of course, has been more patient than my wife, Andrea, and son, Matthew, who forgave me so many nights at the computer.

I trace my appreciation for the environment to growing up on a small New England dairy farm. To work the land is to connect with it; the intimate relationship between air, water, land, and life is seen every aspect of life. I have left the land behind now, both figuratively—I work in the city—and literally—for relaxation, we sail. It is the sailing that now seeds me with the environment, and it is a bittersweet connection. We sail by the grace of nature, propelled by balancing the forces of wind and water. But we sail in a nature disgraced by humans. To depart the harbor, we must first breach the

trash line, a floating windrow of plastic bottles, styrofoam cups, paper trash, old tires and worse. And the return means putting the clear ocean sky behind us to head instead for the orange-brown smudge that heralds yet another urban ozone-alert day.

Petroleum storage tanks, New Haven, Connecticut. See Industry; Petroleum. (©David Zimmerman/Corbis. Reproduced by permission.)

My son, Matthew, is thirteen as I write this. He and his generation are making their own connections with the environment. My hope is that the information presented here will in some small way help them to be better stewards than their parents were.

Richard M. Stapleton

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Vehicular Pollution

WASTE

WATER

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For Your Reference

Below is a list of selected symbols, abbreviations, acronyms, and initialisms that are used regularly throughout the articles in this book.

ACh	acetylcholine
ACM	asbestos-containing materials
ACTION	Activists' Center for Training in Organizing and Networking
AEC	Atomic Energy Commission
AFL	Affiliated Federation of Labor
AFT	American Federation of Teachers
AHERA	Asbestos Hazard Emergency Response Act
AHERA	Asbestos Hazard Emergency Response Amendment
AMD	acid mine drainage
ANILCA	Alaska National Interest Lands Conservation Act
ANWR	Arctic National Wildlife Refuge
AOC	Area of Concern
APA	Administrative Procedures Act
APCA	Air Pollution Control Act
APHIS	Animal and Plant Health Inspection Service
As	arsenic
ATCA	Alien Torts Claims Act
ATSDR	Agency for Toxic Substances and Disease Registry
BCC	bioaccumulating chemical
BCC	bioaccumulative chemical
BCF	bioconcentration factor
BEAR	Business and Environmentalists Allied for Recycling
BHC	benzene hexachloride
BMP	best management practice

BOD	biochemical oxygen demand
BTNRC	Brookhaven Town Natural Resources Committee
BTU	British Thermal Unit
C	carbon
C	Celsius
C-BA	Cost-benefit analysis
C_2H_6	ethane
C_3H_8	propane
$(CH_3)_2Hg$	mercury—methylmercury compound
C_4H_{10}	butane
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAFE	corporate average fuel economy
CAFO	concentrated animal feeding operation
CAP	Campaign Against Pollution
CCA	chromated copper arsenate
CCHW	Citizens Clearinghouse for Hazardous Wastes
Cd	cadmium
CDC	U.S. Centers for Disease Control
CEC	North American Commission for Environmental Cooperation
CEQ	[President's] Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
CGIAR	Consultative Group on International Agricultural Research
CH_3Hg^+	mercury—methylmercury compound
CH_4	methane
ChE	cholinesterase
CHEJ	Center for Health, Environment and Justice
CHP	combined heat and power
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLEAR	Environmental Working Group Clearinghouse on Environmental Advocacy and Research
CO	carbon monoxide

Co	cobalt
CO_2	carbon dioxide
CPAST	Corporation for Public Access to Science and Technology
Cr	chromium
CRJ	United Church of Christ's Commission for Racial Justice
CSD	Commission on Sustainable Development
CSISSFRRA	Chemical Safety Information, Site Security and Fuels Regulatory Relief Act
CSO	Combined Sewer Overflow
CSO	Community Service Organization
Cu	copper
CWA	Clean Water Act
CWS	community water system
DBP	disinfection by-product
DDT	dichlorodiphenyl trichloroethane
DEA	Drug Enforcement Agency
DES	diethylstilbestrol
DHHS	U.S. Department of Health and Human Services
DNA	deoxyribonucleic acid
DNAPL	dense nonaqueous phase liquid
DO	dissolved oxygen
DOA	U.S. Department of Agriculture
DOE	U.S. Department of Energy
DOJ	U.S. Department of Justice
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
E-coli	Escherichia coli
E-FOIA	Electronic Freedom of Information Act
EC	European Community
ECOSO	U.N. Economic and Social Council
ED	effective dose
EDA	Emergency Declaration Area
EDC	ethylene dichloride
EDF	Environmental Defense Fund
EEA	European Environment Agency
EF	ecological footprint

EF!	Earth First!
EFA	ecological footprint analysis
EIA	Energy Information Administration
EIS	environmental impact statement
ELF	Earth Liberation Front
ELF	extremely low frequency
EMF	electromagnetic field
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPI	efflux pump inhibitor
EPR	extended producer responsibility
ERNS	Emergency Response Notification System
EU	European Union
F	Fahrenheit
FBI	Federal Bureau of Investigation
FDA	U.S. Food and Drug Administration
FeS_2	iron sulfide (incl. marcasite and pyrite)
FICAN	Federal Interagency Committee on Aviation Noise
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOIA	Freedom of Information Act
FTC	Federal Trade Commission
FTIR	Fourier transform infrared spectroscopy
FWPCA	Federal Water Pollution Control Act
FWS	U.S. Fish and Wildlife Service
GAC	granular activated carbon
GASP	Group Against Smog and Pollution
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GEF	World Bank's Global Environmental Facility
GEO	geosynchronous Earth orbit
GHG	greenhouse gas
GIPME	Global Investigation of Pollution in the Marine Environment
GIS	Geographic Information System
GLOBE	Global Learning and Observations to Benefit the Environment

GMA	Grocery Manufacturers of America
GPS	Global Positioning System
H	hydrogen
H_2SO_4	sulfuric acid
HAA	hormonally active agent
HAP	hazardous air pollutant
HC	hydrocarbon
HFC	hydrofluorocarbon
Hg	mercury
HGP	Human Genome Project
HgS	cinnabar
HHS	U.S. Department of Health and Human Services
HHW	household hazardous waste
HPLC	high-performance liquid chromatography
HSWA	Hazardous and Solid Wastes Amendment
HYV	high-yielding variety
IADC	Inter-Agency Space Debris Coordination Committee
IAEA	International Atomic Energy Agency
IAP2	International Association for Public Participation
IARC	International Agency for Research on Cancer
IBI	Index of Biotic Integrity
ICC	International Chamber of Commerce
ICP-AES	inductively coupled plasma emission spectra
IDA	International Dark Sky Association
IEGMP	Independent Expert Group on Mobile Phones
IIED	International Institute for Environment and Development
IMF	International Monetary Fund
INPO	Institute of Nuclear Power Operations
IOS	International Organization for Standardization
IPCC	Intergovernmental Panel on Climate Change
IPM	integrated pest management
IR	infrared
ISO	International Organization for Standardization
IWI	index of water indicators
LC	lethal concentration

LC-72	London Convention 1972
LCA	life cycle analysis
LCA	life cycle assessment
LD	lethal dose
LEO	low Earth orbit
LEPC	Local Emergency Planning Committee
LNAPL	light nonaqueous phase liquid
LQG	large-quantity generator
LUST	leaking underground storage tank
MACT	Maximum Achievable Control Act
MACT	Maximum Achievable Control Technology
MARPOL	International Convention for the Prevention of Pollution from Ship 1973
MASSPIRG	Massachusetts Student Public Interest Research Group
MCL	maximum concentration load
MCL	maximum contaminant level
MEO	middle Earth orbit
MGD	million gallons per day
Mha	million hectare
MIT	Massachusetts Institute of Technology
MNA	Monitored Natural Attenuation
MPG	miles per gallon
MSDS	Material Safety Data Sheet
MSW	municipal solid waste
MSWLF	municipal solid waste landfill
MTBE	methyl tertiary-butyl ether
MTD	maximum tolerated dose
MW	megawatt
MWTA	Medical Waste Tracking Act
N	nitrogen
N_2	atmospheric nitrogen
N_2O	nitrous oxide
NAAEC	North American Agreement on Environmental Cooperation
NAAEE	North American Association for Environmental Education
NAAQS	National Ambient Air Quality Standards

NAFTA	North American Free Trade Agreement
NAPL	nonaqueous phase chemical
NAPL	nonaqueous phase liquid
NAS	U.S. National Academy of Sciences
NASA	U.S. National Aeronautics and Space Administration
NCA	Noise Control Act
NEA	National Education Association
NEMO	Nonpoint Education for Municipal Officials
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFWA	National Farm Workers Association
NGO	nongovernmental organization
NH_3	methane
NHGRI	National Human Genome Research Institute
Ni	nickel
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIMBY	not-in-my-backyard
NIOSH	National Institute for Occupational Safety and Health
NO	nitric oxide
NO_2	nitrogen dioxide
NO_3	nitrate
NO_x	nitrogen oxide
NOAA	National Oceanographic and Atmospheric Administration
NOEL	no observable effect level
NORM	Naturally Occurring Radioactive Material
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPL	National Priority List
NPPR	National Pollution Prevention Roundtable
NPRI	National Pollution Release Inventory
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRDA	Natural Resource Damage Assessment

NRDC	Natural Resources Defense Council
NSR	New Source Review
NSRB	Nuclear Safety Regulatory Board
NSTA	National Science Teachers Association
NTC	National Toxics Campaign
O	oxygen
O&M	operations and maintenance
O_2	molecular oxygen
O_3	ozone
ODA	Ocean Dumping Act
OECD	Organization for Economic Cooperation and Development
ONAC	Office of Noise Abatement and Control
OPA	Oil Pollution Act
OPEC	Organization of the Petroleum Exporting Countries
OPP	Oil Pollution Prevention Act
OSHA	Occupational Safety and Health Administration
OTEC	ocean thermal energy conversion
P2	pollution prevention
PAC	polycyclic aromatic compound
PACCE	People Against a Chemically Contaminated Environment
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PBB	polybrominated biphenyl
PBT	persistent bioaccumulative and toxic chemical
PCB	polychlorinated biphenyl
PCC	primary combustion chamber
PCDD	polychlorinated dibenzo dioxin
PCDF	polychlorinated dibenzo furan
PCE	perchloroethylene
PCN	polychlorinated naphthalene
PCP	pentachlorophenol
PCP	Principia Cybernetica Project
PCSD	President's Council on Sustainable Development
PEM	proton exchange membrane
PERC	perchloroethylene

PET	polyethylene terephthalate
PIC	Prior Informed Consent
PIRG	Public Interest Research Group
PM	particulate matter
PO_4^{3-}	phosphate ions or groups
POP	persistent organic pollutant
POTW	publicly owned treatment works
PPA	Pollution Prevention Act
PPCP	pharmaceutical and personal care product
PPE	personnel protective equipment
PrepCom	preparatory committee
PS	polystyrene
PSAC	President's Science Advisory Committee
PV	photovoltaic
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RDF	refuse-derived fuel
ReDo	Reuse Development Organization
RF	radio frequency
RMP	recommended agricultural practice
RRA	Resource Recovery Act
RTK	Right to Know
S	sulfur
SANE	Sane Nuclear Policy
SARA	Superfund Act
SARA	Superfund Amendments and Reauthorization Act
SB	styrene-butadiene
SCC	secondary combustion chamber
SDS	Students for a Democratic Society
Se	selenium
SEED	Schlumberger Excellence in Educational Development
SEJ	Society of Environmental Journalists
SEP	Supplemental Environmental Project
SERC	State Emergency Response Commission
SF_6	sulfur hexafluoride

SHAC	Stop Huntingdon Animal Cruelty
SIP	State Implementation Plan
SLAPP	Strategic Litigation against Public Participation
SMCRA	Surface Mining Control and Reclamation Act
SO_2	sulfur dioxide
SO_4	sulfate
SOC	soil organic carbon
SQG	small-quantity generator
Superfund	Comprehensive Environmental Response, Compensation and Liability Act
SUV	sport utility vehicle
SWDA	Safe Drinking Water Act
TBT	tributyltin
TCDD	tetrachloro dibenzo dioxin
TCE	trichloroethylene
TEF	Toxicity Equivalency Factor
TEPP	tetraethyl pyrophosphate
THM	trihalomethanes
TMDL	Total Maximum Daily Load
TMI	Three Mile Island
TOMS/EP	Total Ozone Mapping Spectrometer on the Earth Probe Satellite
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
TSP	total particulate matter
TT	Treatment Technique
U	uranium
UCC	United Church of Christ
UCS	Union of Concerned Scientists
UFW	United Farm Workers of America
UK	United Kingdom
UN	United Nations
UNCED	U.N. Conference on Environment and Development
UNCHE	U.N. Conference on the Human Environment
UNEP	U.N. Environmental Programme
US	United States of America

USDA	U.S. Department of Agriculture
USGAO	U.S. General Accounting Office
USGS	U.S. Geological Survey
UST	underground storage tank
UV	ultraviolet
VOC	volatile organic compound
WET	Whole Effluent Toxicity
WHB	Workers Health Bureau of America
WHO	World Health Organization
WPA	Works Progress Administration
WRI	World Resources Institute
WSP	Women Strike for Peace
WTC	World Trade Center
WTE	waste to energy
WTO	World Trade Organization
ZID	zone of initial dilution
Zn	zinc
ZPG	zero population growth

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Contributors

David E. Alexander
University of Massachusetts
Amherst, Massachusetts

Paul T. Anastas
Executive Office of the President
Washington, D.C.

Sarah Anderson
Institute for Policy Studies
Washington, D.C.

Mary Jane Angelo
St. John's River Management District
Palatka, Florida

Phillip Anz-Meador
Viking Science and Technology, Inc.
Houston, Texas

Matthew Arno

William Arthur Atkins
Atkins Research and Consulting
Normal, Illinois

Jay Austin
Environmental Law Institute
Washington, D.C.

Pamela Baldwin
Owings, Maryland

Anne Becher
Boulder, Colorado

Elizabeth D. Blum
Troy State University
Troy, Alabama

Brigitte Bollag
Pennsylvania State University
University Park, Pennsylvania

Jean-Marc Bollag
Pennsylvania State University
University Park, Pennsylvania

Arline L. Bronzaft
Lehman College, City University of New York
New York, New York

Joanna Burger
Rutgers University
Piscataway, New Jersey

Dave Brian Butvill
Fontana, Wisconsin

Julie Hutchins Cairn
Seattle Public Utilities
Redmond, Washington

George Carlson
Canterbury, New Hampshire

Elizabeth L. Chalecki
California State University
Hayward, California

Ron Chepesiuk
Rock Hill, South Carolina

Christos Christoforou
Clemson University
Clemson, South Carolina

Allan B. Cobb
Kailua-Kona, Hawaii

Christopher H. Conaway
University of California
Santa Cruz, California

Stacie Craddock
U.S. Environmental Protection Agency
Washington, D.C.

James L. Creighton
Creighton and Creighton, Inc.
Los Gatos, California

José B. Cuellar
San Francisco, California

Raymond Cushman
New Hampshire Department of Environmental Services
Canterbury, New Hampshire

Kenneth A. Dahlberg
Western Michigan University
Kalamazoo, Michigan

Heinz H. Damberger
Illinois State Geological Survey
Boulder, Colorado

Lawrence C. Davis
Kansas State University
Manhattan, Kansas

Joseph E. de Steiguer
University of Arizona
Tucson, Arizona

Larry Deysher
Ocean Imaging
Solana Beach, California

Thomas D. DiStefano
Bucknell University
Lewisburg, Pennsylvania

Bruce K. Dixon
National Association of Science Writers
American Association for the Advancement of Science
Naperville, Illinois

Clive A. Edwards
Ohio State University
Columbus, Ohio

Robert M. Engler
U.S. Army Engineer Research and Development Center
Vicksburg, Mississippi

Christine A. Ennis
National Oceanic and Atmospheric Administration Aeronomy Laboratory
Cooperative Institute for Research in Environmental Sciences
Boulder, Colorado

Larry Eugene Erickson
Kansas State University
Manhattan, Kansas

Gary R. Evans
SE4 Consulting
Potomac Falls, Virginia

Jess Everett
Rowan University
Glassboro, New Jersey

John P. Felleman
State University of New York
Syracuse, New York

Adi R. Ferrara
Bellevue, Washington

Linda N. Finley-Miller
U.S. Army Corps of Engineers
Sacramento, California

A. Russell Flegal
University of California
Santa Cruz, California

David Frame
Oxford, United Kingdom

Ralph R. Frerichs
University of California
Los Angeles, California

David Friedman
Union of Concerned Scientists
Washington, D.C.

David Goldberg
Decatur, Georgia

Janice Gorin

Kevin Graham
Windom Publishing
Denver, Colorado

Robert F. Gruenig
Reynolds, Illinois

Janet Guthrie
National Institute of Environmental Health Services
Research Triangle Park, North Carolina

Charles Hall
State University of New York
Syracuse, New York

Dan Hamburg
Voice of the Environment
Ukiah, California

Ian Scott Hamilton
Texas A&M University
College Station, Texas

Burt Hamner
Seattle, Washington

Donald J. Hanley
Bechtel SAIC Company, LLC
Las Vegas, Nevada

Donald R. Hastie
York University
Toronto, Ontario, Canada

Richard A. Haugland
U.S. Environmental Protection Agency
Cincinnati, Ohio

Denis Hayes
Bullitt Foundation
Seattle, Washington

Patricia Hemminger
New York, New York

Paul Philip Hesse
NCI Information Systems, Inc.
Washington, D.C.

Annette Huddle
San Francisco, California

Craig R. Humphrey
Pennsylavania State University
University Park, Pennsylvania

Susan M. Jablonski
Texas Natural Resource Conservation Commission
Austin, Texas

Betsy T. Kagey
Frostburg State University
Cumberland, Maryland

Corliss Karasov
Madison, Wisconsin

James P. Karp
Syracuse University
Syracuse, New York

Sara E. Keith
State University of New York
Syracuse, New York

Suzi Kerr
Motu Economic and Public Policy Research
Wellington, New Zealand

Leeka Kheifets
World Health Organization
France

Stephen M. Kohn
Kohn, Kohn, & Calapinto
Washington, D.C.

Philip Koth

William Kovarik
Radford University
Radford, Virginia

Michael E. Kraft
University of Wisconsin
Green Bay, Wisconsin

Ashok Kumar
University of Toledo
Toledo, Ohio

Rishi Kumar
Global Educational and Consulting Services
Mississauga, Ontario, Canada

J. Michael Kuperberg
Florida State University
Tallahassee, Florida

Rattan Lal
Ohio State University
Columbus, Ohio

Deborah Lange
Carnegie Mellon University
Pittsburgh, Pennsylvania

Denise M. Leduc
West Bloomfield, Michigan

Terra Lenihan
Denver, Colorado

Peggy Leonard
King County Wastewater Treatment
Seattle, Washington

Lois Levitan
Cornell University
Ithaca, New York

Deena Lilya
Boise, Idaho

David Lochbaum
Union of Concerned Scientists
Washington, D.C.

Tim Lougheed
Ottawa, Ontario, Canada

Adrian MacDonald
Long Island City, New York

Peter S. Machno
Peter S. Machno LLC
Seattle, Washington

Daniel Barstow Magraw
Center for International Environmental Law
Washington, D.C.

Kenneth H. Mann
Bedford Institute of Oceanography
Halifax, Nova Scotia, Canada

Jack Manno
State University of New York
Syracuse, New York

Michael Mansur
The Kansas City Star
Kansas City, Missouri

Burkhard Mausberg
Environmental Defense Canada
Toronto, Ontario, Canada

Michael J. McKinley
U.S. Geological Survey
Reston, Virginia

Glenn McRae
CGH Environmental Strategies, Inc.
Burlington, Vermont

Martin V. Melosi
University of Houston
Houston, Texas

Peter Michaud
Gemini Observatory
Hilo, Hawaii

Bruce G. Miller
Pennsylvania State University
University Park, Pennsylvania

Joel A. Mintz
Nova Southwestern University
Davie, Florida

John Morelli
Rochester Institute of Technology
Rush, New York

Office of Solid Waste/U.S. Environmental Protection Agency
Washington, D.C.

Sunil Ojha
University of Toledo
Toledo, Ohio

Kenneth Olden
National Institute of Environmental Health Services
Research Triangle Park, North Carolina

Christine Oravec
University of Utah
Salt Lake City, Utah

Tim Palucka
Pittsburgh, Pennsylvania

Lee Ann Paradise
Lubbock, Texas

David Petechuk
Rifle, Colorado

P.A. Ramachandran
Washington University
St. Louis, Missouri

Stephen C. Redd
Centers for Disease Control and Prevention
Atlanta, Georgia

William E. Rees
University of British Columbia
Vancouver, British Columbia, Canada

Kevin Anthony Reilly
New York State Supreme Court
New York, New York

Joseph Richey
Boulder, Colorado

Heather V. Ritchie
Tallahassee, Florida

Marin Sands Robinson
Northern Arizona University
Flagstaff, Arizona

Mary Elliott Rollé
National Oceanic and Atmospheric Administration
Department of Commerce
Vermont Law School
Silver Spring, Maryland

Walter A. Rosenbaum
University of Florida
Gainesville, Florida

Joan Rothlein
Oregon Health and Science University
Portland, Oregon

Natalie Roy
The Environmental Council of the States
Washington, D.C.

Joseph N. Ryan
University of Colorado
Boulder, Colorado

Karen M. Salvage
State University of New York
Binghamton, New York

Joseph J. Santoleri
RMT-Four Nines
Plymouth Meeting, Pennsylvania

Michael G. Schechter
Michigan State University
East Lansing, Michigan

Susan L. Senecah
State University of New York
Syracuse, New York

Hollie Shaner
CGH Environmental Strategies, Inc.
Burlington, Vermont

William E. Sharpe
Pennsylvania State University
University Park, Pennsylvania

Lynne Page Snyder
National Academies of Science, Institute of Medicine
Washington, D.C.

Gina M. Solomon
University of California
San Francisco, California

James J. Stapleton
University of California
Parlier, California

Richard M. Stapleton
U.S. Environmental Protection Agency
Washington, D.C.

Donald Stedman
University of Denver
Denver, Colorado

Richard S. Stein
University of Massachusetts
Amherst, Massachusetts

Diana Strnisa
Five Rivers Environmental Education Center
Delmar, New York

Jacqueline Vaughn Switzer
Northern Arizona University
Flagstaff, Arizona

Dorceta E. Taylor
University of Michigan
Ann Arbor, Michigan

Kender Taylor
Seattle, Washington

Christopher M. Teaf
Tallahassee, Florida

Valerie M. Thomas
Princeton University
Princeton, New Jersey

Nathan Thrall

Iris Udasin
Environmental & Occupational Health Sciences Institute
Piscataway, New Jersey

Johan C. Varekamp
Wesleyan University
Middletown, Connecticut

Stephen J. Vesper
U.S. Environmental Protection Agency
Cincinnati, Ohio

Margrit von Braun
University of Idaho
Moscow, Idaho

Frank A. von Hippel
University of Alaska
Anchorage, Alaska

Ted von Hippel

Paul Wapner
American University
Washington D.C.

Linda Wasmer Andrews
Albuquerque, New Mexico

Richard J. Watts
Washington State University
Pullman, Washington

Stefan Weigel
University of Hamburg
Hamburg, Germany

Laura Westra
York University
Toronto, Ontario, Canada

Ross Whaley
State University of New York
Syracuse, New York

Christine M. Whitney
Watertown, Massachusetts

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Abatement

Abatement is a general term used for methods or technologies that reduce the amount of pollutant generated in a chemical or other manufacturing facility. In contrast, the terms cleanup and remediation refer to removal or appropriate disposal of the pollutants after they have been generated; these methods are also often referred to as *end-of-the-pipe treatment.* Current industrial practice places more emphasis on abatement (also known as pollution prevention) and follows the following simple rule: "If you don't make it, you don't treat it."

Pollution abatement involves source reduction, in-process recycling, inplant recycling, design modifications, off-site recycling, and treatment to make the waste less hazardous. Source reduction refers to the examination of various processing units in detail to determine if wastes can be minimized. The step involves several layers of study: (1) Waste inventory is generated. (2) Critical processes leading to waste are identified. (3) Alternative processing strategies are studied to reduce the amount of waste generated in these processes. The collection of waste inventory is an important part of such an analysis. In addition, the inputs that generate these wastes are identified. These data then suggest ideas for source reduction.

In batch reactors, for example, especially in the manufacture of dyestuffs, rinsing of the reactors in between batches is needed to avoid the contamination of the product made in the next batch. This generates a stream of wastewater. The quantity can be reduced by optimal batch scheduling, that is, making similar dyes for a while before switching to a different color. This requires less rinsing between batches since the next dye to be made is of the same color. Another example is the use of solvents. Contaminated solvent from one part of the process may still be good enough for another part of the plant, and the overall generation of the contaminated solvent can be reduced by properly identifying the solvent needs of the entire plant.

In-process recycling refers to the reuse of unreacted materials (after suitable purification) in the same process. Chemical reactions, for example, cannot always be driven to completion due to *thermodynamic limitations.* In such cases, one needs to separate the product from the unconverted raw material, the latter ending up as a waste stream. The waste generation is abated by recycling the raw materials back to the process. The recycling of spent solvent after some needed purification (e.g., carbon adsorption or steam stripping) is another example of this strategy.

The term *abatement* is often used in nontechnical communication to cover a broad range of activities that eliminate or reduce exposure to contamination or toxic substances. Abatement may leave contamination in place, but install some barrier to prevent its migration or exposure to it. Thus, the abatement of lead paint in a home may involve the installation of paneling, new wallboard, or a sealant coating over the old paint. The more specific terms *cleanup* and *removal* are used literally; the contamination is physically cleaned up, removed, and properly disposed of.

In-plant recycling refers to the use of waste generated in one part of the production as a raw material for another part of the plant. Examples of in-plant recycling include solvent reuse and water reuse in the chemical industry.

Design modifications play an important role in waste minimization. Often, minor modifications in the existing equipment can result in considerable waste reduction. The better design of cyclone separators can reduce the number of dust particles exiting a process. For storage tanks, floating roofs are often used in place of fixed roof tanks to avoid "breathing" losses, or losses from a tank when the **ambient** conditions (temperature and pressure) change. For example, if the atmospheric pressure drops, some vapor escapes from the tank in order to equilibrate the pressure, leading to air pollution. Proper insulation can reduce the waste sludge formation in distillation column reboilers because these may now be operated at a lower temperature. A distillation column reboiler is a component of a distillation column and is widely used in refineries and other chemical plants.

ambient surrounding or confined; air: usually but not always referring to outdoor air

Off-site recycling applies to the situation where the waste generated in one plant is a raw material for another industry. For example, gypsum (calcium sulfate) is a waste from stack gas (sulfur dioxide) cleaner in the coal industry, but a raw material in the cement industry. The proximity of industries is an important consideration in off-site recycling since transportation costs can then be minimized. Waste exchange agencies are often able to provide a geographical profile of generated wastes and a description of their potential use in other industries. Once a proper match is established, both parties benefit economically in addition to the reduction in pollution.

If any of the methods suggested here are not applicable, the next step is to examine how to make the waste stream less hazardous. Often, this is an important consideration since the costs for disposal of hazardous wastes are significantly higher than those for nonhazardous wastes. An example is the wastes from a wastewater stream. A single "catch-all" facility is used to collect all the wastewater from different parts of a plant or factory, and this stream is treated or sent to a publicly owned treatment works (POTW) facility. If the wastewater contains hazardous material, then this step may not be followed since the POTW would not accept such a stream. An overlooked solution is the segregation of wastewater (rather than one catch-all combined treatment) and in-process purification. For example, carbon **adsorption** can be used in certain streams before sending it to a catch-all stream. A second example is the treatment of water condensate from chemical reactors. These often contain a significant amount of valuable (but hazardous) raw material. Examples of such contaminants are benzene, toluene, and a variety of low-boiling hydrocarbons. The raw material may be recovered by steam stripping followed by condensation, which recovers it. The raw material is then recycled, and the wastewater from the reactor becomes less hazardous.

adsorption removal of a pollutant from water or air by collecting the pollutant on the surface of a solid material, e.g., an advanced method of treating waste in which activated carbon removes organic matter from waste-water

In summary, a number of techniques discussed here can be used to reduce pollution in manufacturing facilities. Success often depends on engineering experience, insights into the process, and multidisciplinary team efforts. The rewards are a cleaner environment and, in many cases, the added benefit of cost savings and increased profits. SEE ALSO Bioremediation; Brownfield; Catalytic Converter; Cleanup; Technology, Pollution Prevention; Scrubbers; Superfund; Wastewater Treatment.

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P.A. Ramachandran

Acid Rain

Acid rain is any form of atmospherically deposited acidic substance containing strong mineral acids of **anthropogenic** origin. It was reportedly first described in England by Robert Angus Smith in 1872. Acid rain is more properly called acidic deposition, which occurs in both wet and dry forms. Wet deposition usually exists in the form of rain, snow, or sleet but also may occur as fog, dew, or cloud water condensed on plants or the earth's surface. Dry deposition includes solid particles (aerosols) that fall to the earth's surface. Condensation of fog, dew, or cloud water is referred to as occult deposition.

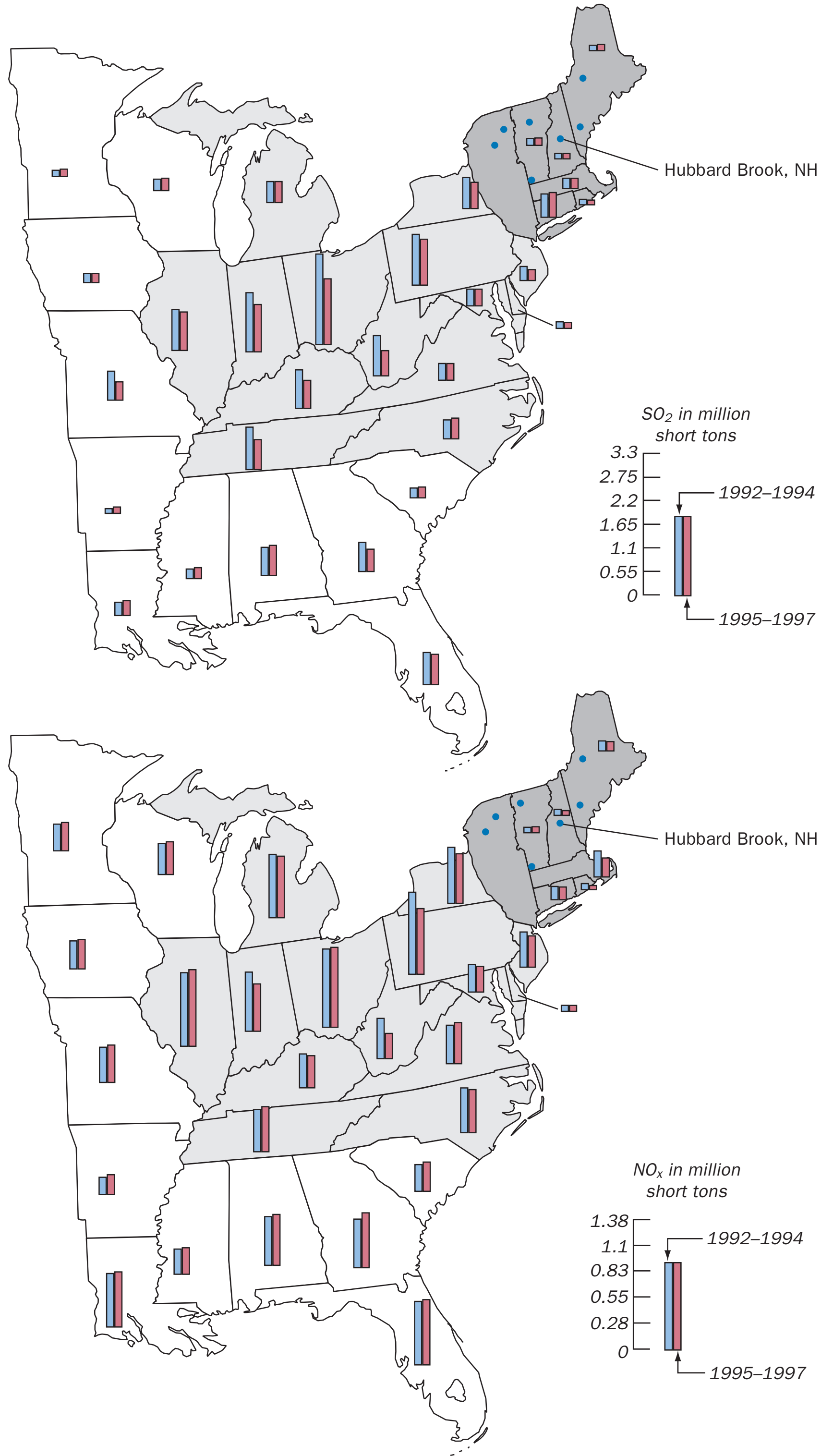
anthropogenic human-made; related to or produced by the influence of humans on nature

The most common acidic substances are compounds containing hydrogen (H^+), sulfates ($SO_4^=$), and nitrates (NO_3^-). The chief source of these compounds is the combustion of fossil fuels such as coal, petroleum, and petroleum by-products, primarily gasoline. Agriculture is also a major source of nitrates. Power plants that burn coal contribute over 50 percent of sulfates to the atmosphere and 25 percent of nitrates.

Prior to the Clean Air Act of 1970, acid deposition was mostly a local problem confined to the immediate vicinity of the pollution source. After 1970, emitters of acidifying pollutants increased the height of smokestacks to reduce local pollution by diluting pollutants in larger volumes of air. The result was the regional transport of acid deposition to remote locations. Acid rain has adversely affected large areas of the mountainous regions of the eastern United States and Canada, Scandinavia, central and Eastern Europe, and parts of China. Areas that are downwind of heavy concentrations of power plants receive the most deposition.

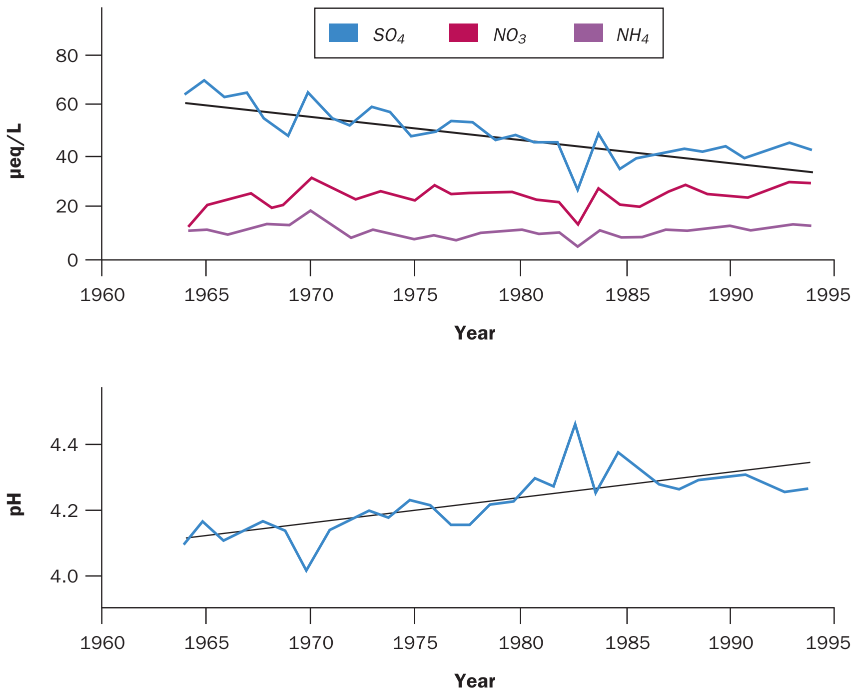
Acid rain acidifies soils with low calcium carbonate levels, which results in the acidification of water passing through the soil to streams and lakes. Calcium carbonate soil-buffering capacity is related to soil origin. Soils weathered from rocks high in calcium carbonate have high calcium carbonate buffer capacity. Fish and other aquatic life have been eliminated from streams and lakes by acid deposition. Continued acid deposition leaches calcium and magnesium from the soil and results in the increased mobility of aluminum, which is toxic to both animals and plants. Aluminum is always present in soils, but it is innocuous until mobilized into soil water by acidic deposition. Its presence in water in small amounts will cause the outright

SPATIAL PATTERNS OF SULFUR DIOXIDE AND NITROGEN OXIDE EMISSIONS IN THE EASTERN UNITED STATES



SOURCE: Driscoll, C. T.; G. B. Lawrence; A. J. Bulger; T. J. Butler; C. S. Cronan; C. Eager; K. F. Lambert; G. E. Likens; J. L. Stoddard; and K. C. Weathers. (2001). *Acid Rain Revisited: Advances in Scientific Understanding since the Passage of the 1970 Clean Air Act Amendments*. Hubbard Brook Research Foundation. Science Links™ Publication, Vol. 1, No. 1.

LONG-TERM TRENDS IN SULFATE, NITRATE, AND AMMONIUM CONCENTRATIONS AND pH IN WET DEPOSITION AT THE HBEF, 1963–1994



SOURCE: Driscoll, C. T.; G. B. Lawrence; A. J. Bulger; T. J. Butler; C. S. Cronan; C. Eager; K. F. Lambert; G. E. Likens; J. L. Stoddard; and K. C. Weathers. (2001). *Acid Rain Revisited: Advances in Scientific Understanding since the Passage of the 1970 Clean Air Act Amendments*. Hubbard Brook Research Foundation. Science Links™ Publication, Vol. 1, No. 1.

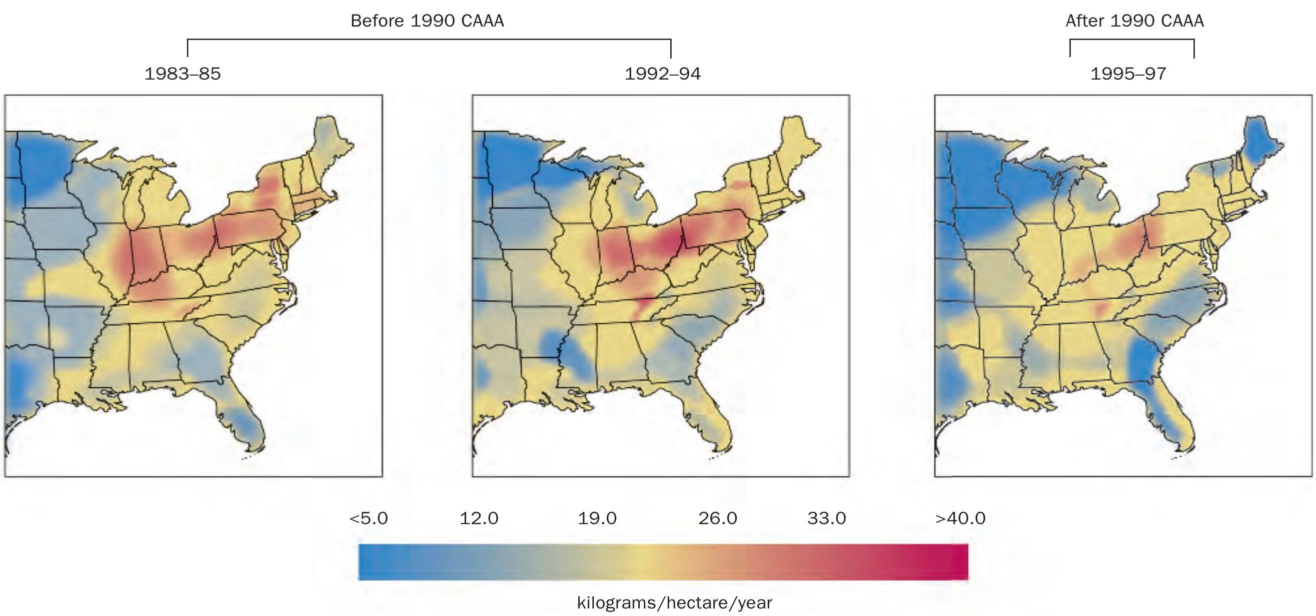
death of fish and other aquatic life, disrupt normal fish spawning, and reduce populations of many species of aquatic insects.

Acid forest soils are thought to cause forests to decline and grow more slowly. Soil acidity causes nutrient deficiencies in trees and other plants and predisposes them to attack by pathogens such as insects and fungi. Soil acidity also increases photo-oxidant stress in plants. Monuments and buildings made of marble or other forms of calcium carbonate and statuary made of certain metals such as copper are also damaged by acid deposition. The acidification of waters leads to increases in mercury uptake by fish, causing them to be unsafe to eat.

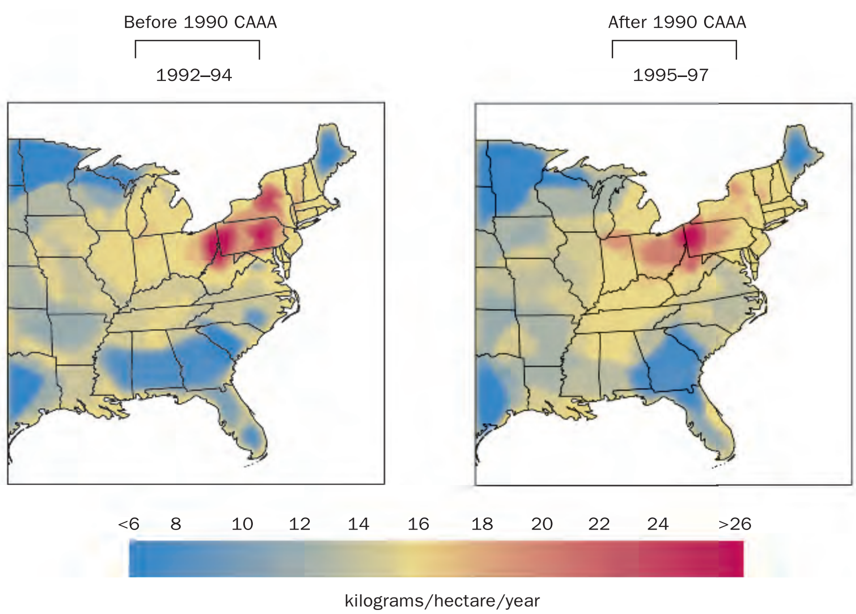
The governments of the European Economic Community, Canada, and the United States have taken steps to reduce the emissions of sulfate and nitrates. The Clean Air Act Amendments of 1990 were designed to reduce U.S. emissions of sulfate by about 40 percent through a program of emissions trading between emissions generators, use of low-sulfur coals (fuel switching), and controls on power plant smokestack emissions. Although this program has significantly reduced acidic deposition in many parts of the northeastern United States, many scientists agree that additional reductions will be required to prevent continued damage and allow for meaningful recovery of affected lakes and streams. SEE ALSO AIR POLLUTION; COAL;

RECENT PATTERNS OF WET DEPOSITION BEFORE AND AFTER IMPLEMENTATION OF THE 1990 CAAA

Sulfate Wet Deposition



Nitrate Wet Deposition



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ELECTRIC POWER; NO_x (NITROGEN OXIDES); PETROLEUM; SULFUR DIOXIDE; VEHICULAR POLLUTION.

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William E. Sharpe

Activism

"In wildness is the preservation of the world," wrote Henry David Thoreau, a nineteenth-century New England writer who became a founding figure of today's environmental movement. His life and work ushered in a uniquely American perspective on nature, a philosophy that made an unprecedented defense of the value of wilderness. In so doing, he diverged dramatically from long-standing philosophical traditions that place human interests above the actions of the natural world.

Historical Roots: Running out of Wilderness, Running into Opposition

Thoreau (1817–1862) showed that a sense of wonder and inspiration could be found in "raw" nature, which human beings had traditionally regarded as chaotic, foreboding, or downright dangerous. He relied on personal experience, monitoring seasonal changes in the plant and animal life around him, writing accounts of his trips to the mountains and rivers of Maine, and spending extended periods of time living in a primitive cabin on Walden Pond in Massachusetts. He made no apologies for flouting society's conventions. Instead, he offered his eccentric lifestyle as an example of how an appreciation of the natural world could enhance human existence. Nor was he afraid to challenge society's rules, outlining the virtues of "civil disobedience" in a famous essay about a night he spent in jail over a matter of conscience.

The natural world of Thoreau's day needed little defending, in spite of the polluting factories of the industrialized northeast United States. The rest of North America contained vast amounts of unclaimed, unsettled land. Wilderness might be daunting, but it appeared to be inexhaustible, and our technology at the time did not seem to have the potential to exhaust it.

It was a century after Thoreau's death that the passion he embodied would evolve into a much more aggressive form of action. This evolution formed a response to the immense economic growth in North America during the period following World War II. People sought bigger houses and more cars, causing cities and road systems to sprawl across the landscape. The accumulation of material wealth exacted a price on the natural world, a toll that became increasingly visible during the 1950s.

By the 1960s, environmental degradation was becoming obvious even to those who did not pay much attention to the natural world. The air and water in many places had become badly polluted, often by industrial wastes as well as by the garbage generated by rapidly growing urban centers. In 1966 some eighty New Yorkers died when warm summer air raised the city's smog levels past what many people could tolerate. A year later an offshore oil rig in California fouled beaches with millions of gallons of spilled oil. In 1969 the Cuyahoga River near Cleveland, Ohio, spontaneously burst into flames, so choked had it become with unstable chemical effluents.

Likewise boaters on Lake Erie had been encountering huge patches of floating algae, which were being fed by large volumes of industrial and agricultural runoff, especially phosphorus. The algae, in turn, robbed the lake bottom of oxygen, rendering the water incapable of sustaining fish life. In the early 1960s, scientists began measuring phosphorus levels dozens of times

Marion and Barney Lamm became known as the "Sacrificial Lamms" after they voluntarily closed their prosperous fishing lodge on Salt Lake, Ontario, to protest the coverup of mercury contamination. Mercury levels twenty-eight times the upper federal limit were found in lake fish and Minimata Disease was found in local Ojibway Indians. The Lamm's twenty-year fight to protect the Ojibway is chronicled in fifty-nine boxes of documents now housed at the Harvard University Library.

higher than a typical, unpolluted lake. Their findings—coupled with the evidence of dead fish piling up on Erie shores—made for strident news stories citing local residents and politicians who declared the lake to be "dying." In a foreshadowing of public outcries to come, a Cleveland car dealer named David Blaushild collected one million signatures on a petition to save the lake. He submitted the document to the Ohio governor's office in 1965, setting in motion a vigorous international campaign.

The 1960s: Silence and Shouting

In 1962 American biologist Rachel Carson published *Silent Spring*, an account of the environmental damage that had been caused by widespread use of the pesticide DDT. Like Thoreau, Carson was regarded by many critics as little more than a philosophical and scientific crank. But Carson's book put forth serious charges in scientific detail. The use of DDT had been hailed for saving millions of lives in Europe by killing insects that spread typhus and malaria. At the same time, she pointed out, residual amounts of this chemical were also killing beneficial insects such as honeybees, as well as fish, birds, and other animals.

By portraying the environmental consequences of this pesticide, Carson unleashed a fierce controversy. Representatives of chemical and agricultural industries tried to discredit her work, insisting that the impact of DDT was not as significant as she suggested. Others defended Carson, arguing that the long-term harm DDT caused to the natural world outweighed any short-term benefits to human beings. Gradually, other scientists mustered evidence to echo the conclusions of *Silent Spring*. Within a decade the U.S. government—which had originally hailed the advent of DDT in the 1940s—banned its use.

Carson's book, and the legislation that emerged as a result, reflected the tenor of a turbulent decade. The iconic image of the 1960s is that of a young person carrying a protest sign, a sight that seemed to symbolize the coming of age for a populous, rebellious, and affluent generation whose members began to be born immediately after the end of World War II in 1946. Although this image is a stereotype, many individuals and organizations lodged a wide range of public grievances with the authorities of the day. Such protests cultivated new attitudes toward civil rights, women's rights, foreign policy, and military affairs, as well as toward the environment. Many of these topics were already being debated by political leaders and social commentators. Carson's work appeared just as the calls for change were growing louder.

Some tentative federal measures to address environment had already been implemented. The 1948 Federal Water Pollution Control Act sparked the beginning of active House and Senate Public Works Committee interest in this issue. Similarly, an Air Pollution Control Act went into effect in 1955. But a much more dynamic process began with a White House Conservation Conference in 1962. This event drew together officials from all levels of government to consider matters of conservation, natural resources, and public health. The next few years would see the passage of a much more specific Clean Air Act, the Wilderness Act, the Solid Waste Disposal Act, the National Wild and Scenic Rivers Act, the National Environmental Policy Act, and the creation of the National Wildlife Refuge System.

This parade of legislation did not unfold smoothly, however. Even as protesters urged the passage of each new law, vested interests mounted their

own opposition. Battles that began in the street moved into the courts and occasionally spilled back into the streets. Some of the most contentious disputes dealt with air quality, spawning grassroots movements in major urban centers. Dubbed the "Breathers' Lobby" by the *Wall Street Journal*, these groups included GASP in Los Angeles, the Metropolitan Washington Coalition on Clean Air, and the Delaware Clean Air Coalition. One of their most memorable moments came during the first Earth Day in 1970, when protesters marched through downtown Pittsburgh in gas masks carrying a coffin to demonstrate against the poor quality of that city's air.

The Rise of Rights

The physical state of the world was beginning to emerge as a primary consideration for the protest movements of the 1960s. While a task like cleaning up a dirty river might seem to be relatively straightforward, Rachel Carson and other biologists were furnishing the public with graphic evidence of a much greater challenge. Their steadily advancing knowledge of the science of ecology was shedding light on the intricate web of biological connections that sustains any living environment. Even when outright pollution was not evident, human activities could damage this web in many different ways.

This perspective came to the fore in 1966, when the U.S. Bureau of Reclamation announced plans for two dams on the Colorado River that would flood more than 100 miles of the Grand Canyon. Since the 1930s, dam building had been deemed to be a laudable sign of progress, bringing power into isolated rural communities and meeting the ever-increasing demand for electricity in cities. Compared with alternatives such as coal-burning generating stations, hydroelectric dams were a source of energy with few environmental consequences. Although flooded valleys were among those consequences, floods were often cast in a positive light: the resulting artificial lakes offered new recreational uses. On the other hand, the Grand Canyon was not just another valley, but a sentimental favorite of casual tourists and die-hard naturalists alike. The proposal sparked unprecedented environmental ire.

At the head of this backlash was the Sierra Club, the country's oldest conservation organization. Founded in 1892, it had played a major role in shaping policies on forestry practice and the emerging national parks system at the beginning of the twentieth century. For several decades it had remained a much more passive organization, but the Grand Canyon controversy revived its active stance. David Brower, who had been the club's executive director for fourteen years, made the issue a major focus. He took out newspaper advertisements outlining the dam proposal, complete with coupons and instructions for lodging complaints with appropriate members of government. The Sierra Club ordered two movies to be made, printed up bumper stickers and pamphlets, and reprinted its own colorful coffee table book on the Grand Canyon. By 1967 the *New York Times* had dubbed the organization's members "gangbusters of the conservation movement." The fracas led one senator to conclude, "Hell hath no fury like a conservationist aroused."

That fury became swiftly evident. Mail, telegrams, and phone calls flooded government offices, so much so that the Internal Revenue Service revoked the Sierra Club's tax exempt status because of its substantial lobbying efforts. That move only further galvanized public opinion, which would swell the club's membership from 39,000 in 1966 to 67,000 by 1968. By then

the dam proposal had been irrevocably defeated, but much more than that had been accomplished. Dams could no longer be built without questions being asked; they had lost their unshakable status in public opinion. Rivers, too, had rights.

Giving the Earth Its Due

The notion of "environmental rights" was sometimes characterized as a citizen's right to a clean environment. Regardless of the specific wording, this perspective fueled efforts to give these issues a different kind of legal standing. Lawyers and ecologists found themselves working together through the Environmental Defense Fund, a body created in 1967. Its founders had successfully defeated a bid by the massive power utility Consolidated Edison to store water in a huge mountain reservoir on the Hudson River, where it could be released to provide hydroelectricity at times of excess demand. Opponents of the project cited the potentially negative environmental effects of such releases, and the court agreed. Moreover, when the company appealed on the basis of the fact that none of the people suing would be directly affected by any water releases, the court made life even more difficult for companies such as Consolidated Edison. Not only did the appeal decision give citizen groups the right to protect the environment for noneconomic reasons, but it also made industrial firms responsible for drafting "environmental impact statements" before undertaking such major ventures.

Buoyed by this outcome, the Environmental Defense Fund embarked on a concerted strategy of environmental legislation. Wielding lawsuits and court injunctions, they targeted everything from simple industrial pollution to the construction of nuclear reactors. Problems such as the contamination of soil with heavy metals, which had seldom had a high public profile, were suddenly thrust into the limelight by the Environmental Defense Fund. Popular media began bandying about the term "ecology," which previously had been familiar to only a few scientists. Subtle concepts such as the "food chain" became widely discussed, as did the assertion that humans now had the power to make the planet unable to sustain human life. Since the dawn of the cold war in the 1950s, the major threat to the existence of human life appeared to be the radiation that would linger after a major nuclear conflict. Now an equally gloomy picture was being drawn by those who accused humanity of ruining the natural systems that had nurtured us for millions of years.

Astronauts provided the most poignant image to accompany this accusation, a photograph of the earth in its entirety, as seen from the moon. Reproduced in magazines, school textbooks, and posters, the sight of this "big blue marble" reinforced the argument that we dwelled in a world of finite resources, with natural boundaries that we ignored at our peril. Nor was this message lost on hundreds of thousands of people who began to join conservation groups like the Sierra Club. During the course of the 1960s, that organization saw its membership quintuple to 113,000. Similarly, the Wilderness Society doubled its membership to 54,000, the Audubon Society doubled its to 81,500, and the National Wildlife Federation doubled its to 540,000.

For some observers, this widespread realization of our world's boundaries had come none too soon. In 1968 Italian industrialist Aurelio Peccei assembled a meeting of scientists, economists, educators, and government

administrators to discuss this subject. That gathering spawned the Club of Rome, a think tank that soon issued a report called *The Limits to Growth*. The report sounded some of the most dire warnings yet that our population and technological capabilities could soon reach the "carrying capacity" of the planet. Without dramatic recycling and conservation initiatives, the report said, key resources such as petroleum, metals, and minerals would be in such scarce supply as to be all but gone. Similarly, we would find viable farmland and clean water to be no less scarce unless we worked harder at preserving the integrity of our ecosystems.

The call for a new relationship between human beings and nature prompted many people, including Gaylord Nelson, a senator from Wisconsin, to take action. Using his own funds, Nelson set about organizing Earth Day, a national event to promote a better understanding of environmental issues. Since young people were to play a critical role in the activities, the chosen day was April 22, 1970, when most of the nation's college students could be expected to have completed their exam schedule. When it arrived, no fewer than 10,000 schools and 2,000 colleges and universities held special classes for the occasion. There were nature hikes, garbage cleanup campaigns, and formal presentations about pollution. Larger cities hosted huge rallies and street fairs. And although it was almost impossible to determine the total number of participants across North America, estimates ran as high as twenty million.

Earth Day is still marked every April 22, though with somewhat less fanfare than on that first occasion. For many people, it was a proud and consummate expression of the protest movements that characterized the 1960s. Direct action in the name of the environment would seldom take such a massive and spontaneous form again. Instead, the decade opened by Earth Day would welcome a much more carefully planned brand of activism.

In 1972, the Club of Rome, an international think tank, published *The Limits to Growth,* warning that man-made damage to nature was expanding to such an extent that it might put at stake the very survival of humankind. The book was highly controversial, coming at a time of high public optimism following a period of immense economic growth in both the Western and Communist worlds. *The Limits to Growth* was based on one of the first efforts (at MIT) to apply computer modeling to economy and the environment. It sold twelve million copies in thirty-seven languages.

The 1970s: A Very Green Decade

The legal achievements of the Environmental Defense Fund demonstrated the virtues of organized activism, pointing the way for other interested parties that wanted to follow suit. Organizations sprang up year after year, employing the talents of individuals with expertise in the rapidly developing field of environmental law. Some of those individuals became famous in their own right, such as American lobbyist Ralph Nader—who founded the Public Interest Research Group in 1970 as one of the first independent "watchdog" agencies on environmental regulation—and French mariner Jacques Cousteau, whose Cousteau Society drew worldwide attention to the state of the world's oceans. Other agencies that were formed about the same time went on to become household names: Friends of the Earth, Union of Concerned Scientists, League of Conservation Voters, and the Worldwatch Institute.

No such list would be complete without Greenpeace, which continually set higher standards for the most dynamic of these organizations. This definitive collection of environmental activists assembled in 1970 by way of responding to a somewhat different cause—the U.S. testing of nuclear weapons under Amchitka Island, part of the Aleutian Island chain off Alaska. The group consisted of antiwar protesters who feared the outcome of a nuclear arms race, many of them expatriate Americans who had moved to Canada to avoid being drafted into the war in Vietnam. Others were Sierra Club members, voicing their own fears of deep-sea seismic activity set off by

an underground nuclear explosion, which could lead to tidal waves or earthquakes along North America's west coast. Searching for a name at their initial meeting in a church basement in Vancouver, British Columbia, these distinct elements posed the words "green" and "peace," until the connection was ultimately made.

Following a fund-raising concert, Greenpeace chartered an old fishing boat, and later, a retired minesweeper. In October 1971, members and news reporters sailed on these vessels up the west coast toward Amchitka, hoping to arrive before the next scheduled bomb test at the beginning of November. Some of the people who went on this voyage admit that it seemed like a crazy thing to do, and they had little idea of what would happen once they got there. Deteriorating fall weather prevented the fishing boat from reaching the island, and the sturdier minesweeper failed to reach it before the test. Nevertheless, the trip succeeded beyond anyone's expectations. News outlets were able to provide gripping coverage of the adventure and, more importantly, the reason for that adventure in the first place. Embarrassed by this extraordinary attention, the federal government subsequently abandoned its underground testing program. As it turned out, Greenpeace did not need to achieve its stated goal to achieve a much loftier objective: exposing problems that might otherwise elude public notice.

Greenpeace learned this lesson well and began applying it elsewhere. The group chose whaling as its emblematic example of human assault on the natural world, a brutal slaughter of mammals whose intelligence was considered to be comparable to our own. Greenpeace became intimately associated with the expression "save the whales" after its ships began intercepting whaling vessels at work on the high seas. Taking great personal risks by maneuvering small boats in front of whales as they were being targeted by harpoons, Greenpeace activists filmed what they found and ensured that this visual record made its way to television news outlets. In some cases the very act of recording these encounters was enough to cause the whalers to stop what they were doing and leave.

All too frequently, such daring tactics were met with mockery, anger, and the odd outbreak of violence, but they got results. By adding drama to the earlier legislative momentum, Greenpeace helped turn the 1970s into an era of groundbreaking environmental measures. The process was already well under way in 1970, when the U.S. federal government created the Environmental Protection Agency as the bureaucratic cornerstone for an emerging regulatory regime. Over the next few years, clean water and clean air laws would be repeatedly revised. New controls would be placed on all kinds of toxic substances. Legal protection would be provided to endangered species by safeguarding their habitat, even when such protection hampered business interests.

And the activist posture born in the United States was being exported. "Green" parties, with political platforms explicitly premised on environmental topics, emerged in New Zealand in 1972 and in the United Kingdom in 1973. By the end of the decade similar parties would appear in four other European countries, most prominently in West Germany, where substantial numbers of members gained elected office. This trend had a profound influence in Europe, where citizens were facing all of the same environmental challenges as in the United States, but where governments had done little to

Greenpeace members handcuffed together and sitting on steel drums similar to toxic waste drums outside of the Mexican Office of Environmental Protection, calling attention to the toxic waste disposal facility at Guadalcazar, San Luis Potosi, owned by the U.S. company Metalclad Corporation, Mexico City, Mexico, July 19, 1995. (AP/Wide World Photos. Reproduced by permission.)

respond to these challenges. Green party politics, raising environmental issues in the very seat of a nation's government, became an important means of prompting laws and regulations.

But perhaps the most ambitious initiative arrived on the scene by way of the United Nations. In 1972, in Stockholm, the United Nations held a Conference on the Human Environment, endorsing a list of twenty-six environmental principles and creating a new body to oversee them. This agency, called the United Nations Environment Programme, was based in Nairobi, Kenya, and employed more than 1,000 people. It became the model and basis for creating thousands of nongovernmental organizations (NGOs) operating in all parts of the globe, focusing on various aspects of environmental management. Many still do good work, but not all of these NGOs would be free of political influence, and some would prove to be ineffectual or downright incompetent. Yet they stood on the front lines of a growing number of international treaties for dealing with environmental issues. From 1930 to 1971, forty-eight such treaties were negotiated. Between 1971 and 1980, another forty-seven were added.

The 1980s: The Pendulum Swings

Just as the protests of the 1960s gave way to a more orderly environmental agenda in the 1970s, this agenda took a decidedly different turn in the 1980s. The decade opened with Congress introducing the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), known as

Julia "Butterfly" Hill examining damage done to an ancient redwood, called Luna by activists, from a chainsaw. Supports were bolted into the tree. (Shaun Walker/ OtterMedia.com. Reproduced by permission.)

Superfund. This law created a tax on industries that would be dedicated to cleaning up releases or threatened releases of hazardous substances in the environment. Over the next five years CERCLA brought in some $1.6 billion for this purpose, creating a trust fund to deal with abandoned or uncontrolled hazardous waste sites.

This kind of genuine environmental progress, resulting in well-defined, well-enforced, and well-funded rules, had stemmed from a combination of grassroots activism and political pressure. Individuals were encouraged to "think globally, act locally" (i.e., interpret a general environment topic through actions they could take immediately, such as tackling water pollution by lobbying factory owners to clean up industrial runoff that was being dumped into a nearby river). At the same time, political leaders were eager to take action to address the dire warnings of pessimistic groups such as the Club of Rome. Harsh pollution rules, for example, often raised the operating costs and lowered the profits of the industries that were doing the polluting. Many politicians were taking a long-term view of the environment, but it was costing them political support in the short term.

In 1980 much of that support disappeared. In the wake of economic recessions throughout much of the 1970s, voters mounted a conservative backlash. Led by President Ronald Reagan, political figures stated bluntly that too much attention had been paid to environmental matters that affected

few people at any time, while too little attention was being paid to economic problems that affected far more people on a day-to-day basis. The environment would not necessarily be ignored, but the needs of industry would be given much more weight. Little environmental legislation moved forward during Reagan's definitive eight-year term, and a great deal of existing legislation was weakened or set aside.

Grassroots support fared little better, as the focus in many communities became ever narrower. Where people were formerly being asked to reject water pollution in principle, local protests were increasingly premised exclusively on what was happening locally. Known as the "not in my backyard syndrome," these actions might keep a polluting industry out of a particular region that could organize opposition to it, but they did not muster the broader political will to keep that industry from polluting anywhere at all. This fragmentation of protest ensured that environmental legislation would not move forward.

Moreover, environmental science—which had given the initial push to the entire movement—was becoming bogged down in controversy. Qualified experts began sparring publicly with the pessimistic conclusions of the Club of Rome. These opponents maintained that the carrying capacity of our planet is much greater than *The Limits to Growth* suggested. And, they added, our own capacity for technological innovation is even more profound. Even were we to "run out" of some key resource, we are inventive enough to find a way around this shortcoming. As for the damage we are inflicting on the earth's ecology, some researchers began to compare it with the damage done by the earth itself. These investigations noted that a natural phenomenon like a volcano emits far more air pollution than any number of smokestacks, and that subtle climatic changes could alter water temperature enough to kill off far more aquatic species than any industrial waste.

Even a decade-long $600 million study of acid rain, which drew on the work of some 2,000 scientists, proved to be inconclusive. The physical process appeared to be simple enough: human activities were emitting large amounts of sulfur into the atmosphere, which subsequently came down in highly acidic raindrops, which in turn led to the acidification of lakes and rivers. Yet the research incorporated a great deal of competing evidence to show that these bodies of water often went acidic without any human influence, and had been doing so for thousands of years. When the final report was presented in 1990, its conclusions were objective but so thorough and multifaceted that they failed to form the basis for any concrete action on the problem.

Other major environmental matters met the same fate in public forums. Scientists wrangled over the meaning of huge "holes" that had been discovered in some parts of the earth's atmosphere. The holes were defined by the absence of ozone—airborne oxygen molecules that normally screen out harsh radiation from space. Some observers linked the holes with the use of chemicals that were being used in refrigeration and spray-can technology. Others countered that the holes came and went at random, implying that they were merely natural occurrences that we had finally discovered. The chemicals were eventually banned, but there is still no firm consensus on ozone holes. In contrast, a similar scientific controversy over global warming emerged in the 1990s. While doubters continued to be heard, enough of a consensus was

established to draft an agenda for concerted international action that was enacted in several nations.

Such muddles, combined with the conservative tenor of the times, vexed environmental activists. They wanted their issues back on the public agenda, even if truly radical action were required.

Violent Turns

Some members of Greenpeace had seen the conservative backlash coming even before the presidential election of 1980. According to Canadian member Paul Watson, the essential response had to be increasingly militant protest actions. Among other things, he did not want merely to scare away whalers by filming them; he advocated placing explosives on the hulls of their ships in order to cripple their livelihood. Greenpeace rejected such tactics, and in 1977 it rejected him as well. He formed his own organization, called the Sea Shepherds, outfitted with a refurbished ship that had been renamed *Sea Shepherd.* Watson described the 200-foot trawler as "the first ship in history dedicated to the enforcement of international marine wildlife conservation law." Whales, he added, now had their own navy.

That navy's first skirmish came off the coast of Portugal in 1979, when the *Sea Shepherd* rammed a ship that was illegally taking whales. Despite the attack, and Watson's willingness to own up to it for the authorities, the owners of the ship refused to press charges because of the publicity a trial would generate. In this way, the Sea Shepherds attempted to augment the public exposure that Greenpeace had found so effective in quelling environmental offenses. Watson regarded himself as offending the offenders, daring them to strike back.

Some members of Greenpeace might have admired his dedication and nerve, but they would not have been inclined to admit it publicly. Taunting authority was one thing, but menacing it with illegal action was a line that many conscientious members of society refuse to cross. Watson continued to cross it as often as he could. And as the political atmosphere of the 1980s began to wear down the environmental movement, he was joined by others.

In 1980 American activist Dave Foreman felt the same frustration as Watson. "Too many environmentalists have grown to resemble bureaucrats," said Foreman. "Pale from too much indoor light; weak from sitting too long behind desks; co-opted by too many politicians." By way of response, he founded Earth First!, an organization aimed at putting activists like himself back in the middle of the fray. Earth First! led skirmishes that ranged from high-profile pranks—such as hanging a symbolic "crack" down the face of an unwanted dam—to outright sabotage, such as wrecking logging or road-building equipment in wilderness areas. These more serious offenses were labeled "ecotage," and the group took great pride in making them as inventive and disruptive as possible. In particular, Earth First! was linked with a practice known as tree-spiking, randomly nailing large spikes deep into trees in a logging area. Loggers and mill workers were then warned that some of these trees might contain these large pieces of metal, which could cause serious injury if they were struck with a saw blade. Forestry workers felt threatened, and logging companies remained unsure of how to deal with this tactic, even though it appears that there has never been a proven case of personal harm caused by tree spiking.

Julia Hill, atop an ancient redwood tree. (Shaun Walker/OtterMedia.com. Reproduced by permission.)

Others have taken such radical action a step further. Citing a philosophy called deep ecology, these activists accord animals the same inherent rights as any human being. From this viewpoint, animals raised for food on farms or being used in laboratory experiments deserve to be "liberated." Groups dedicated to this purpose have gone so far as to break into research facilities and remove the animals. When such vandalism became more common in the mid-1980s, the scientific community was shocked. Soon, however, that response gave way to a more concerted campaign to raise awareness of the ways in which animal experimentation can promote the well-being of both animals and humans. In addition, the use of animals has become subject to ever-closer scrutiny, fostering a regulatory framework that has steadily reduced their use, in favor of other experimenting and testing methods.

While none of these initiatives may be enough to satisfy the most extreme elements of the animal-rights movement, members of that movement are highly diversified. Some criticize the extremists for idealizing animals, as well as for ignoring the violence and brutality that often mark the lives of creatures who already find themselves "liberated" in the wild. In this way, moving from a purely philosophical outlook to a more broadly based scientific understanding of the issue, many environmental activists retreated from the most radical positions and began searching for more practical and effective.

The 1990s: Managing in the Mainstream

When the environment initially entered the forum of public discussion in the 1960s, many of its ideas were profoundly novel. Some people did not welcome or even understand the argument that a river flowing in the uninhabited wild could be more important to human existence indirectly than a dam that could deliver power directly to millions of human beings. Today many of us still have difficulty accepting the premise that a seldom-seen plant or animal might play a part in the global ecosystem that is every bit as crucial as our own. Activists continue to press for a wider appreciation of the complexities that abound in environmental science, even as the scientists continue to struggle with those complexities.

For better and for worse, therefore, a great deal of the thinking of environmental activists has now entered the social and cultural mainstream. The language of environmental activism has been embraced by members of the political and business establishment. Action occasionally follows on the heels of these words, but the most appropriate course can be far from clear. A leading example of this dilemma was the debate over climate change that developed at the end of the twentieth century. Furious debate swirled around the possibility that human industrial activity was increasing the level of carbon dioxide in the earth's atmosphere sufficiently to cause a "greenhouse effect," raising the average temperature. If so, major environmental changes could be expected, including the loss of major cropland and the raising of the sea level.

For many observers, it remained unclear how climate change might be demonstrated or disproved. Nevertheless, a 1997 conference in Kyoto, Japan, offered an international set of protocols that would limit each country's output of "greenhouse gases" according to the nature of its economy and its landmass. Only a handful of countries have so far endorsed the Kyoto Protocol, including Japan, Britain, Germany, New Zealand, and Canada. But Australia

and the United States have rejected the terms of the agreement, severely hampering efforts to address a global problem with a global response.

Similar difficulties have plagued grassroots initiatives. For instance, a five-year effort was carried out to persuade McDonald's to abandon its use of foam-plastic packaging, which does not break down in landfills. In 1991 the Environmental Defense Fund struck a deal with the fast-food giant, which agreed to use paper wrapping. Although the decision was hailed as a victory, critics quickly pointed out that this alternative would lead to just as much waste and environmental damage. The fundamental problem—overpackaging—had not been resolved.

Even Earth First! founder Dave Foreman eventually cut his ties with that organization and its methodology. In 1991 he began to lead the Wildlands Project, which works cooperatively with private and public landowners to set up buffer zones around park areas. Earth First!, for its part, still pulls off some occasional extreme action. Serious damage has also been carried out by a more shadowy organization called the Earth Liberation Front, which in 1998 took responsibility for burning down part of a Colorado ski resort near a designated wilderness site.

Going Global, Going Simple

As the ideas voiced by environmental activists entered the mainstream, so too did a sense that those voices should also represent the mainstream. Groups such as Greenpeace have begun to examine the diversity of their own membership, which has traditionally been dominated by white males. Women have steadily joined, and a separate philosophical position known as ecofeminism appeals to both environmental activists and representatives of long-standing women's groups. By recruiting women as well as individuals from various ethnic or cultural backgrounds, the environmental movement can also offset a perception that it speaks primarily for affluent North Americans. That charge has followed lobbying efforts in developing nations such as Brazil, where activists have advocated limits on road building and logging in the Amazon rain forest. Many Brazilians resent the suggestion of economic restrictions coming from representatives of other nations that have already inflicted environmental damage on their regional ecosystems in order to further their own economic growth.

In fact, much more attention is being paid to the suggestion that economic development may well be the best way to protect the environment. Economists argue that poor countries fare much worse in environmental terms, using less efficient technology and lacking the transportation and communication systems to promote activities such as recycling. This assertion is still hotly debated, but it surfaces during discussions of globalization, the issue that now generates far more of the traditional style of protest activity than the environment. Young people who a generation ago marched in the street to announce their opposition to nuclear war or toxic waste can today be found marching in the streets to announce their opposition to a market-driven economic model that became dominant in the 1980s.

In this respect, therefore, the ambitions of environmental activists have returned to some of the original priorities of the 1960s, such as targeting major developments like dams rather than appealing to a desire to see rivers

free of pollution. But an environmental consciousness continues to thrive, instilled in the popular imagination and often enshrined in law. Concerned citizens no longer need to commit outrageous acts in order to foster an appreciation of our impact on the natural world. As the twenty-first century begins, our way of life is dominated by technologies that ensure that we can obtain as much information about the environment as we could ever want. The challenge that lies ahead is not that of becoming aware of the environment, but determining how we will act on that awareness.

And perhaps the most revealing trend may be to act less. A movement known as voluntary simplicity has found favor among individuals who find themselves accumulating more and more material wealth but gaining less and less satisfaction from it. The next stage of activism may amount to limiting this accumulation, reducing what we take from the natural world in order to benefit both ourselves and the environment. That prospect contains an irony that would not be lost on Henry David Thoreau. "I would rather sit on a pumpkin and have it all to myself," he wrote, "than be crowded on a velvet cushion." SEE ALSO Addams, Jane; Agenda 21; Air Pollution Control Act; Antinuclear Movement; Arctic National Wildlife Refuge; Brower, David; Cancer Alley, Louisiana; Carson, Rachel; Chávez, César E.; Clean Air Act; Clean Water Act; Commoner, Barry; DDT (Dichlorodiphenyl trichloroethane); Disasters: Chemical Accidents and Spills; Disasters: Environmental Mining Accidents; Disasters: Natural; Disasters: Nuclear Accidents; Disasters: Oil Spills; Earth Day; EarthFirst!; Earth Summit; Ehrlich, Paul; Environmental Justice; Ethics; Gibbs, Lois; Government; Green Party; Green Revolution; Hamilton, Alice; History; LaDuke, Winona; Laws and Regulations, International; Laws and Regulations, United States; Lifestyle; Limits to Growth; Nader, Ralph; National Environmental Policy Act (NEPA); National Toxics Campaign; New Left; Nongovernmental Organizations (NGOs); Ocean Dumping; Popular Culture; Population; Poverty; Progressive Movement; Public Interest Research Groups (PIRGs); Public Participation; Treaties and Conferences; U.S. Environmental Protection Agency; Warren County, North Carolina; Writers; Zero Population Growth.

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Tim Lougheed

Adaptive Management

Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Traditionally, management plans for addressing the impacts of pollution, and addressing the risks of exposure of toxics to humans and ecosystems were strictly followed as written. If the plan needed to be changed, a complex policy process needed to be engaged to change it. However, managers have increasingly acknowledged the scientific uncertainty about what policy or practice is "best" for a particular management issue. A good example is restoring a polluted river system's water quality and fisheries. New understandings about ecosystems, human health, and the impacts of pollution and toxic exposure have led to management practices that can adapt along the way. Hence, adaptive management is being increasingly incorporated into agreements and decisions that mandate managers to address a problem using the best available science rather then an inflexible set of directives. Rather than being static, this repeating management cycle consists of 1) assessing the problem, 2) designing a management program designed to address the problem and reveal gaps in knowledge, 3) implementing the program, 4) monitoring the effects of it according to key indicators, 5) evaluating the program based on these indicators, and 6) adjusting the program in light of this. Often, this is done through a collaborative process that considers all the interests who have a stake in the resource. SEE ALSO Consensus Building; Health, Human; Mediation; Natural Resource Damage Assessment; Precautionary Principle; Public Policy Decision Making; Regulatory Negotiation.

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Susan L. Senecah

Addams, Jane

Jane Addams (1860–1935) is remembered primarily as the feisty American founder of the Settlement House Movement, which sought to challenge the industrial and urban order of the period to achieve social and environmental reforms. Inspired by a visit to London's East End and Toynbee Hall, a "settlement house" addressing the needs of the urban poor, Addams and her friend Ellen Starr cofounded Hull House in the slums of Chicago in 1889. Hull House became the central organizing hub and political force to provide social services to the exploding number of immigrants coming to Chicago to work in the unregulated factories. The living and working conditions around industrialized Chicago were horribly unsanitary, unhealthy, stinking, and crowded, and the politics were fairly corrupt.

Addams's Hull House confronted questions of housing, sanitation, and public health, areas not typically seen as being connected. A major campaign attacked the inadequate and inequitable garbage collection in the neighborhoods of crowded tenements. Addams's unsuccessful bid for the contract to

Jane Addams. (©Bettmann/ Corbis. Reproduced by permission.)

collect the city's garbage gained so much publicity that the mayor appointed her to be Chicago's garbage inspector. In this role, Addams was so successful in raising public awareness of the situation that restructuring the garbage collection system quickly rose to the top of the agenda of both City Hall and the reform movement. She was also a mover and a shaker in the areas of labor reform, especially around fighting for industrial safety, humane worker conditions, and labor unions, and against child labor. Much of her work led to the right to vote for women. In 1910 Yale University awarded Addams the first honorary degree ever bestowed on a woman. In 1931 she received the Nobel Peace Prize, becoming the first American woman to receive a Nobel Prize. SEE ALSO Activism; Settlement House Movement; Solid Waste.

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Susan L. Senecah

Agencies, Regulatory

There are large numbers of federal and state agencies in the United States that have been authorized by Congress or state legislatures to implement and enforce environmental laws. As a general matter, environmental regulatory agencies are responsible for establishing maximum allowable levels of pollutants in air, water, and soil to protect human health and the environment, and for developing programs to achieve such levels of protection. Most environmental regulatory programs are carried out through permitting programs under which releases of pollutants are allowed provided they meet established standards or limits, and other conditions imposed by the regulatory agency.

On the federal level, the Environmental Protection Agency (EPA) is the primary regulatory agency responsible for pollution control. It was created in 1970 as an outgrowth of the environmental movement in the United States during the 1960s, although at that time a number of federal environmental programs already existed. These programs were scattered throughout several different federal agencies. The creation of the EPA was an attempt to consolidate these environmental programs under the control of one agency with clear-cut responsibility for environmental protection. The EPA is funded through congressional appropriation; it carries out wide-ranging duties related to environmental protection, including researching the causes and effects of specific environmental problems; regulating air pollution, water pollution, solid and hazardous waste disposal, pesticides and toxic substances; providing oversight of states that have assumed responsibility for federal environmental programs; and enforcing environmental laws.

In addition to federal environmental regulation, virtually every state has an agency responsible for pollution control. Many of these state agencies were established by state legislatures shortly after the creation of the EPA. State environmental agencies may receive their funding from a variety of sources, including legislative appropriation, property taxes, and grants from the EPA and other federal agencies. The extent and type of state regulation

can vary widely. Some states, such as California, New Jersey, and Michigan, have very extensive pollution control programs, whereas others have minimal programs. The nature of such programs depends in large part on the kind of environmental issues facing the state and their magnitude, the size of the state, the economy of the state, and the political leanings of state residents. For example, California, a large progressive state with serious air quality problems, has extensive regulatory programs, particularly in the area of air pollution control. One California regulatory agency is the California Air Resources Board, a part of the California Environmental Protection Agency, which develops and implements regulations to reduce emissions from motor vehicles. Some states have all or most of their pollution control responsibilities concentrated in one agency, often called a state Department of Environmental Protection or Department of Environmental Quality. Pollution control responsibilities in other states may be shared by a number of agencies, including public health agencies, natural resources agencies, and fish and wildlife agencies, or in media-specific agencies such as California's Department of Water Resources.

In the case of many EPA regulatory programs, the EPA designs the programs and then delegates their implementation and enforcement to state agencies. In fact, this is true of the majority of federal environmental laws administered by the EPA. Most of the major permitting programs that the EPA oversees, including the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act, contain specific provisions authorizing it to delegate administration of the programs to those states that have permitting systems which meet the minimum federal criteria. Through such delegation, the EPA limits its role to designing regulatory programs and issuing the rules to carry them out. EPA enforces regulations only in those states that have not adopted programs meeting federal standards. Even when the EPA delegates a program to a state, though, it maintains an oversight role, having the authority to enforce permit requirements and veto state permits.

Outside of the United States, many other developing countries, particularly in the West, have agencies responsible for environmental protection that are very similar in structure and scope to the EPA. For example, Germany, France, and Great Britain all have national environmental agencies with primary responsibility for the regulation of air and water pollution, and public and hazardous waste disposal. SEE ALSO ENVIRONMENT CANADA; MEXICAN SECRETARIAT FOR NATURAL RESOURCES (LA SECRETARÍA DEL MEDIO AMBIENTE Y RECURSOS NATURALES); U.S. ENVIRONMENTAL PROTECTION AGENCY.

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Mary Jane Angelo

Agenda 21

Agenda 21, agreed to at the United Nations Conference on Environment and Development (more commonly known as the Earth Summit) in Rio de Janeiro in 1992, was the nonbinding plan of action that identified and prioritized environmental, financial, legal, and institutional issues to serve as a guide for countries to direct their resources and energies. Among Agenda 21's most notable elements were calls for the creation of the Commission on Sustainable Development (CSD), whose functions include monitoring the agenda's implementation and conducting negotiations toward a treaty on **desertification**, a high-priority concern of many developing countries.

desertification transition of arable land to desert

The language of Agenda 21 accommodated the more developed countries' preferences for limiting environmental damage, as well as the developing countries' concerns about economic growth and foreign assistance in support of that growth. Critics, however, contend that the agenda's attention to global warming, population growth, and species extinction demonstrates its partiality to the concerns of developed nations.

At the time of a subsequent Earth Summit, Rio + 5, in 1997, the consensus was that some progress had been made in terms of institutional development, international **consensus-building**, public participation, and private-sector actions, and that, as a result, a number of countries had succeeded in curbing pollution and slowing the rate of resource degradation. But, despite this progress, the global environment continued to deteriorate. Advocates of Agenda 21 persevere; they agreed that the CSD would be the central organizing body for Rio + 10, officially called the 2002 World Summit on Sustainable Development. SEE ALSO EARTH SUMMIT; SUSTAINABLE DEVELOPMENT; TREATIES AND CONFERENCES.

consensus-building negotiation to create agreement

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Michael G. Schechter

Agriculture

Agriculture, the deliberate raising of plants and animals to enhance and secure food production, evolved in the Near East about 10,000 years ago. It was this transition from hunting-gathering to settled agriculture that created civilization as we know it and led to a rapid increase in the human population from about five to six million at that time to six billion in 2000. Although the term *agriculture* literally means field cultivation, in a broader context it

A worker wearing protective clothing is spraying crops with pesticides. (U.S. EPA. Reproduced by permission.)

implies the conversion of natural to managed ecosystems in order to produce adequate and continual food supply.

Traditional Agricultural Systems

Demands for an increase in food production were initially met by expanding the area being cultivated or horizontal expansion. The cropland area increased from 265 million hectares (Mha) prior to the Industrial Revolution in 1700 to 1,500 Mha in 1980, representing an increase of 5.7 times in less than three centuries. (One hectare equals 2.47 acres.) The scarcity of new land for crop production necessitated increasing crop production per unit area and time from the same land. This need for agricultural intensification, or vertical expansion, has been satisfied by the use of chemical fertilizers, supplemental irrigation, improved **cultivars,** and intensive cropping systems.

cultivar a plant variety that exists only under cultivation

Soil fertility refers to reserves of plant nutrients (e.g., N, P, K, Ca, Mg, Zn, Cu, Mo, S, and B) in the root zone and their availability to cultivated plants in accord with physiological needs. Most ancient civilizations evolved on soils with built-in fertility rejuvenation mechanisms. These included **alluvial** soils along the floodplains of major rivers (e.g., the Nile, Indus, Euphrates, and Tigris) or **loess** soils with a continuous source of plant nutrients through wind-blown materials (e.g., the Loess Plateau of China). With an increase in population, agriculture expanded into other regions where the nutrient supply was not renewed on a regular basis by flood water or wind deposits. In regions with adequate water supply, nutrients stored in the forest biomass were released for crop production through the "slash and burn" method. Soil fertility was restored by *land rotation* or *shifting cultivation* in which a short cultivation period of two to three years was followed by long fallow or a rest period of fertility restoration. The land was used extensively and productivity was low.

alluvial relating to sediment deposited by flowing water

loess soil deposited by wind

In these systems, farms were small and based on mixed farming systems with the close integration of crops with livestock. This involved the

incorporation of hay or meadows in the rotation cycle. Crop residues and hay were fed to livestock and manure redistributed on the land.

With the wide availability of fertilizers since World War II, farms in North America and other developed economies have become larger, leading to the increased predominance of **monoculture** and the elimination of hay and meadows from the rotation cycle. Animal production operations have become specialized, based on feedlot, creating a problem of manure management on the one hand and depletion of soil organic carbon (SOC) stock on the other.

monoculture large-scale planting of a single crop species

Soil Fertility Enhancement by Chemical Fertilizers

The use of supplemental nutrients to increase crop yield started as trial and error in the form of wood ashes, ground bones, salt peter, and gypsum. Justus von Liebig (1803–1873), a German chemist, laid the foundation for the use of chemical fertilizers as a source of plant nutrients starting in 1840. He recognized the importance of various mineral elements derived from the soil in plant nutrition and the necessity of replacing those elements in order to maintain soil fertility. Two British scientists, J.B. Lawes and J.H. Gilbert, in turn established the agricultural experiment station at Rothamsted, in the United Kingdom. They built on the work of Liebig and experimentally demonstrated the importance of chemical fertilizers in improving and maintaining soil fertility. In fact, the application of synthetic fertilizers was the basis of the global increase in agricultural production after World War II.

Global fertilizer use was merely 27 million tons in 1959 and 1960; it increased five times to 141 million metric tons over the forty-year period ending in 2000. The projected fertilizer demand for the year 2020 is 220 million metric tons. Intensive fertilizer use on input-responsive cultivars grown on prime irrigated land was the basis of the green revolution in South Asia and elsewhere that saved millions from hunger and malnutrition. As the world population increases and cropland becomes more valuable, total cropland acreage is beginning to diminish, increasing the reliance on fertilizer.

Similar to fertilizer use, there has also been a rapid increase in global pesticide use. In fact, much of the success of the green revolution depended on the use of pesticides. Global pesticide use was four million tons in 1970, five million tons in 1985, and six million tons in 2001. As much as 85 percent of all pesticides are used in agriculture. The misuse of pesticides can cause severe environmental problems, especially in developing countries. It is estimated that chemical pollution in agriculture costs about $100 billion in diverse public health and environmental damage each year worldwide. The health risks are due to a lack of or inadequate occupational and other safety standards, insufficient enforcement, poor labeling, illiteracy, and insufficient knowledge about the hazards of pesticides and fertilizers.

Supplemental irrigation has been used to raise crops in arid regions since 9500 to 8000 B.C.E. Irrigated agriculture developed in the Middle East, South Asia, China, and in Central and South America. Irrigation played a major role in increasing food production during the nineteenth and twentieth centuries. Irrigated land area had expanded to 275 Mha by 1998. Worldwide, 17 percent of irrigated cropland produces 40 percent of the world's food.

The leakage of fertilizers into the environment adversely impacts water quality (i.e., nonpoint source pollution) and exacerbates the greenhouse

CAFOs or Concentrated animal feeding operations pose major environmental risks because of the large quantities of animal waste that they produce. A 10,000-hog CAFO produces as much waste in a single day as a town of 25,000 people. In 1997, a toxic algae called *Pfiesteria,* linked to manure from giant chicken factories, polluted the waters of the Chesapeake Bay, killed thousands of fish, sickened more than a dozen people, and put the bay's entire seafood industry at risk. *Pfiesteria* has been implicated in more than 50 percent of the fish kills in North Carolina coastal waters.

effect (i.e., emission of N_2O and NO_x). Fertilizer use efficiency can be enhanced by the adoption of conservation tillage and incorporation of cover crops in the rotation cycle. Cover crops include grass species sown between the main crops to improve soil quality and increase the SOC pool, or **leguminous** crops that enhance soil fertility through biological nitrogen fixation. Species of *Graminaceae* and *Cruciferae* are **nitrate catch crops** and produce biosolids/residues to be used as mulch. Nitrate catch crops minimize the leaching of nitrates available in the soil, and undersown catch crops are more efficient than those established after the harvest of main crops.

leguminous members of the pea family, or legumes

nitrate catch crop crop planted to harvest soil nitrates

Agriculture and the Environment

Inappropriate land use, soil mismanagement (especially the practice of plowing and growing monoculture with the subsequent need for large amounts of pesticides), and the adoption of fertility-mining practices can have adverse impacts on the environment, including the **eutrophication** of surface water, contamination of ground water, and emission of greenhouse gases (GHGs) from agricultural ecosystems into the atmosphere. Processes that lead to environmental pollution include accelerated erosion, leaching, volatilization, mineralization of organic matter, **methanogenesis**, and denitrification. These processes are accentuated by the conversion of natural to agricultural ecosystems, biomass burning, plowing and other excessive soil disturbance, indiscriminate use of fertilizers and other farm chemicals such as pesticides and herbicides, and drainage of wetlands. Nonetheless, these activities were deemed necessary to increase agricultural productivity to meet the demands of an increased population during the nineteenth and twentieth centuries.

eutrophication in nature, the slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears; in pollution, excess algal growth or blooms due to introduction of a nutrient overload of nutrients, i.e., from un- or poorly treated sewage

methanogenesis creation of methane gas by microbes

Intensive Commercial Agriculture in Developed Countries. Agricultural pollution in developed countries such as the United States is caused by the excessive use of chemicals. In the United States, the use of synthetic pesticides since 1945 has grown thirty-three-fold to about 0.5 billion kilograms (kg) per year or 3 kg per hectare per year. Further, the increase in hazard is even greater than it might appear because the toxicity of modern pesticides has increased by more than ten-fold over those pesticides used in the early 1950s. U.S. data show that 18 percent of all pesticides and about 90 percent of all fungicides are carcinogenic. In addition to humans, thousands of domestic animals are also poisoned by pesticides in the United States. The destruction of natural predators and parasites is costing the nation more than $500 million each year and resulting in the development of pesticide resistance. Ground and surface water contamination from pesticides is a serous issue. The excessive use of fertilizers and plowing can cause the eutrophication of water and transport sediment-borne chemicals into surface water. The average fertilizer use is about 100 kg per hectare per year in North America and 200 kg per hectare per year in western Europe. If use efficiency is less than 60 percent, a large proportion of the fertilizer applied ends up in surface and ground waters, or as a gaseous emission (N_2O and NO_2) into the atmosphere.

Low-Input Agriculture in Developing Countries. The shifting cultivation and related **bush-fallow** systems, practiced in sub-Saharan Africa and elsewhere in the tropics, rely on cycling nutrients accumulated in vegetation and the soil surface during the fallow period. Deforestation and biomass burning emit large quantities of particulate matter and GHGs into the atmosphere. Further, the mineralization of SOC to release plant-available nutrients (e.g.,

bush-fallow practice of alternating between cultivating a piece of land and leaving it unplanted

Organic farming is the raising of crops and products using natural fertilizers and cultural and biological pest management. It excludes the use of synthetic chemicals in crop production and prohibits the use of antibiotics and hormones in livestock production. The U.S. Department of Agriculture (USDA) implemented national organic standards on organic production and processing in October 2002 and products meeting those standards are "certified organic." USDA reports in 2002 that about 1 percent of oats, dry beans, tomatoes, grapes, and citrus were grown organically and about 2 percent of dry peas and lentils, 3 percent of apples, 4 percent of carrots, and 5 percent of lettuce was organic.

N, P, K, Ca, Mg, Zn, etc.) gives off CO_2 and other GHGs into the atmosphere. The release of 50 kg of N per hectare through the decomposition of soil organic mater would lead to the emission of 500 kg of CO_2-C, if we assume a conservative C:N ratio of 10:1. The problem is drastically exacerbated by accelerated soil erosion, which is a widespread problem due to harsh climate and fragile soils. Soil nutrient depletion at a continental scale continues to be a major problem in Africa, with severe economic and environmental consequences. The average annual nutrient loss on arable land in Africa was 22 kg N per hectare, 2.5 kg P per hectare, and 15 kg K per hectare.

Intensive Agriculture in Developing Economies. The rapidly growing human population in Asia (particularly in the southern or eastern regions of the continent) has jeopardized the environment and natural resources, which are already under great stress. Consequently, off-farm input (e.g., fertilizers, pesticides, irrigation, plowing) plays an important role in food production in India, China, Thailand, Malaysia, Indonesia, etc. In India, approximately 59 million kg of pesticides are applied to agriculture annually. The average rate of fertilizer application in East Asia is 240 kg per hectare per year. Because of N subsidies, for example, farmers apply the cheap N pesticide and do not consider using the more expensive but less toxic P and K products. Consequently, there is a nutrient mining of soil in intensive rice-wheat areas. Further, highly soluble chemicals are quickly leached into the ground water. India is one of only two countries worldwide (along with the United States) to have applied more than 100,000 tons of dichlorodiphenyl trichloroethane (DDT) since its initial formulation. Because of the excessive and indiscriminate use of pesticides in India, the total intake of organochemicals per person in that country is the highest in the world.

Despite the problems outlined here, the adoption of recommended agricultural practices (RMPs) can enhance food production with minimal risks to the environment. In addition to the use of improved varieties responsive to input, RMPs include conservation-till or no-till farming involving cover crops in the rotation cycle, integrated nutrient management based on a judicious use of chemical fertilizers in combination with manures and other biosolids, precision farming to apply nutrient and chemicals based on soil-specific needs, soil-water management through drip irrigation/fertilization, or subirrigation through controlled water table management, etc. The objective is agricultural intensification on existing land. It means cultivating the best soil with the best management practices to produce the optimum sustainable yield and save agriculturally marginal lands for nature conservancy.

Sustainable Agriculture

There are numerous, diverse, and increasing demands on agriculture in the twenty-first century. In addition to meeting the demands for the economic production of food, feed, fiber, and fuel, agriculture of the twenty-first century must also address environmental concerns, especially in regard to water quality and the accelerated greenhouse effect. Soil is a biofilter, and a reduction in the thickness of the topsoil layer through erosion has a direct negative effect on the buffering and filtering capacity of the soil and on the emission of greenhouse gases into the atmosphere. Soil erosion preferentially removes soil organic matter because it is light and is concentrated in the surface layer. A large fraction of the C thus displaced by water runoff may be prone to

mineralization, leading to its emission into the atmosphere as CO_2. It is estimated that globally 1.1 billion tons of C may be emitted annually as CO_2 because of displacement by water erosion. In addition, some of the organic matter deposited in depressional sites and aquatic ecosystems may lead to the emission of methane (CH_4) and nitrous oxide (N_2O). In comparison to CO_2, the global warming potential is twenty-one for CH_4 and 310 for N_2O.

Sustainable agriculture, therefore, is a viable production system based on environmentally benign agricultural practices. The objective of sustainable agriculture is to enhance and sustain production while improving soil fertility, soil tilth, and soil health. While enhancing production, sustainable agriculture must also address environmental issues with regard to water quality and the greenhouse effect. Rather than being the cause, improved agriculture is a solution to certain environmental problems.

Sustainable agriculture implies profitable farming on a continuous basis while preserving the natural resource base. It is not synonymous with low-input, organic, or alternative agriculture. In some cases, low input may sustain profitable and environmentally sound farming. In others, it might not. The addition of organic amendments might enhance soil quality, but may not eliminate the need for the judicious use of fertilizers. Large quantities (10 to 20 ton/hectare/year) of organic manures are needed to supply enough nutrients to produce the desired yields. Therefore, the use of organic manures, although desirable, may not be logistically feasible. In sub-Saharan Africa, low inputs on impoverished soils and low yields have been responsible for low standards of living, severe malnutrition, and widespread problems of soil and environmental degradation. Therefore, the adoption of RMPs is a necessary prerequisite to feeding the earth's expected ten billion inhabitants by the year 2100. Judicious management includes the conversion of marginal agricultural soils to restorative land use and adoption of RMPs. Technological options differ among soils, ecoregions, and social and cultural settings, but the underlying basic principles remain the same. SEE ALSO CARVER, GEORGE WASHINGTON; CRYPTOSPORIDOSIS; GREEN REVOLUTION; INTEGRATED PEST MANAGEMENT; PESTICIDES.

Raising poultry is big industry on Maryland's Eastern Shore, but there's a problem. The 600 million birds annually create about 800,000 tons of chicken manure. They may soon be creating electricity. Environmentalists, the poultry industry and local officials are enthusiastically studying plans to build a 40-megawatt power plant that would burn chicken manure mixed with wood shavings to generate electricity. Fibrowatt, the British company making the proposal, already operates three poultry-manure-powered generating plants in England and is currently building a plant in Minnesota to be powered by turkey manure.

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Rattan Lal

Air Pollution

Air pollution is a phenomenon by which particles (solid or liquid) and gases contaminate the environment. Such contamination can result in health effects on the population, which might be either chronic (arising from long-term exposure), or acute (due to accidents). Other effects of pollution include damage to materials (e.g., the marble statues on the Parthenon are corroded as a result of air pollution in the city of Athens), agricultural damage (such as reduced crop yields and tree growth), impairment of visibility (tiny particles scatter light very efficiently), and even climate change (certain gases absorb energy emitted by the earth, leading to global warming).

Air pollution is certainly not a new phenomenon. Early references to it date back to the Middle Ages, when smoke from burning coal was already such a serious problem that in 1307 King Edward I banned its use in lime kilns in London. More recently, there have been major episodes of air pollution, such as the 1930 catastrophe in the Meuse Valley, Belgium, where SO_2 and particulate matter, combined with a high relative humidity, caused sixty-three **excess deaths** in five days. In 1948 similar conditions in Donora, Pennsylvania, a small industrial city, caused twenty excess deaths in five days,

excess death deaths over the expected number

The New York City skyline on a smoggy day in the 1960s. (©Roger Wood/Corbis. Reproduced by permission.)

U.S. NATIONAL POLLUTANT EMISSION ESTIMATES FOR 1999
(thousand short tons)

Source Category	CO	NO_x	VOC	SO_2	PM_{10}	$PM_{2.5}$	Total
On-road Vehicles	49,989	8,590	5,297	363	295	229	64,763
Non-road Vehicles	25,162	5,515	3,232	936	458	411	35,714
Miscellaneous	9,378	320	716	12	20,634	4,454	35,514
Fuel Combustion	5,322	10,026	904	16,091	1,029	766	34,138
Electric Utilities	445	5,715	56	12,698	255	128	19,267
Industrial	1,178	3,136	178	2,805	236	151	7,684
Other	3,699	1,175	670	588	568	487	7,187
Waste Disposal and Recycling	3,792	91	586	37	587	525	5,618
Solvent Utilization	2	3	4,825	1	6	6	4,843
Metals Processing	1,678	88	77	401	147	103	2,494
Other Industrial Processes	599	470	449	418	343	191	2,470
Chemical Manufacturing	1,081	131	395	262	66	40	1,975
Storage and Transport	72	16	1,240	5	85	31	1,449
Petroleum Industries	366	143	424	341	29	17	1,320
Total	97,441	25,393	18,145	18,867	23,679	6,773	190,298

SOURCE: Adapted from http://www.epa.gov/ttn/chief/trends/trends99/tier3_1999emis.pdf.

and in the early 1950s in London, England, two episodes of "killer fogs" claimed the lives of more than 6,000 people.

Classification of Air Pollutants

Not all pollutants are a result of human activity. *Natural pollutants* are those that are found in nature or are emitted from natural sources. For example, volcanic activity produces sulfur dioxide, and particulate pollution may derive from forest fires or windblown dust. *Anthropogenic pollutants* are those that are produced by humans or controlled processes. For example, sulfur dioxide is produced by fossil fuel combustion and particulate matter comes from diesel engines.

Air pollutants also are classified as *primary* or *secondary.* Primary pollutants are those that are emitted directly into the atmosphere from an identifiable source. Examples include carbon monoxide and sulfur dioxide. Secondary pollutants are those that are produced in the atmosphere by chemical and physical processes from primary pollutants and natural constituents. For example, ozone is produced by hydrocarbons and oxides of nitrogen (both of which may be produced by car emissions) and sunlight. See the table for a listing of estimated pollutant emissions in the United States in 1999.

Air Pollution Control Laws and Regulations

The earliest programs to manage air quality in the United States date to the late 1880s; they attempted to regulate emissions from smokestacks using nuisance law municipal ordinances. Little progress was made in air pollution control during the first half of the twentieth century.

In the 1950s there was a shift away from nuisance law and municipal ordinances as the basis for managing air quality toward increased federal involvement. The Air Pollution Control Act of 1955 established a program for federally funded research grants in the area of air pollution, but the role of the federal government remained a limited one.

NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Standard Value*		Standard Type
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary
Nitrogen Dioxide (NO_2)			
Annual Arithmetic Mean	0.053 ppm	(100 µg/m^3)	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.12 ppm	(235 µg/m^3)	Primary & Secondary
8-hour Average	0.08 ppm	(157 µg/m^3)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 µg/m^3		Primary & Secondary
Particulate (PM 10) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 µg/m^3		Primary & Secondary
24-hour Average	150 µg/m^3		Primary & Secondary
Particulate (PM 2.5) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean	15 µg/m^3		Primary & Secondary
24-hour Average	65 µg/m^3		Primary & Secondary
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	0.030 ppm	(80 µg/m^3)	Primary
24-hour Average	0.14 ppm	(365 µg/m^3)	Primary
3-hour Average	0.50 ppm	(1300 µg/m^3)	Secondary

*Parenthetical value is an approximately equivalent concentration.

SOURCE: U.S. Environmental Protection Agency

It was the Clean Air Act (CAA) of 1963 that further extended the federal government's powers in a significant way, allowing direct federal intervention to reduce interstate pollution.

The Clean Air Act Amendments (CAAA) of 1970 continued many of the programs established by prior legislation; however, several aspects of it represented major changes in strategy by expanding the role of the federal government. The 1970 CAAA defined two types of pollutants that were to be regulated: criteria and hazardous pollutants.

Criteria pollutants, regulated to achieve the attainment of the National Ambient Air Quality Standards (NAAQS), including primary standards for the protection of public health, ". . . the attainment and maintenance of which, . . . allowing an adequate margin of safety, are requisite to protect public health," and secondary standards for the protection of public welfare. The first six criteria pollutants were carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), total suspended particulate matter (TSP), hydrocarbons, and photochemical oxidants. Lead was added to the list in 1976. In 1979 the photochemical oxidants standard was replaced by one for ozone (O_3), and in 1983 the hydrocarbons standard was dropped altogether. In 1987 TSP was changed to PM_{10}, and in 1997 $PM_{2.5}$ was added to the official list and the ozone standard revised.

National Emission Standards for Hazardous Air Pollutants (NESHAP) were established. A *hazardous air pollutant* (HAP) was defined as one "to which no ambient air standard is applicable and that . . . causes, or contributes to, air pollution which may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible or incapacitating reversible illness." Examples include asbestos, mercury, benzene, arsenic, and radionuclides.

ESTIMATED POLLUTANT EMISSIONS IN THE UNITED STATES IN 2000
(Thousand short tons)

Source Category	CO	NO_x	VOC	SO_2	PM_{10}	$PM_{2.5}$
Fuel combustion						
Electric utilities	445	5,266	64	11,389	270	141
Industrial	1,221	3,222	185	2,894	244	157
Other	2,924	1,161	957	593	483	458
Chemical manufacturing	1,112	134	407	268	67	41
Metals processing	1,735	91	79	411	152	107
Petroleum industries	369	146	433	346	30	17
Other industrial processes	620	487	480	432	355	198
Solvent utilization	2	3	4,827	1	7	6
Storage and transport	74	17	1,225	5	87	32
Waste disposal and recycling	3,609	89	582	35	544	514
On-road vehicles	48,469	8,150	5,035	314	273	209
Nonroad vehicles	29,956	5,558	3,404	1,492	436	400
Miscellaneous	20,806	576	2,710	21	21,926	5,466
Total	109,342	24,899	20,384	18,201	24,875	7,746

SOURCE: EPA data available from http://www.epa.gov/ttn

Even though the CAAA of 1970 and 1977 placed deadlines on the dates for compliance with the NAAQS, as of 1990 in many areas of the United States, a variety of criteria pollutants existed in concentrations greater than the standards allowed.

As a result, the CAAA of 1990 were passed. They contain eleven major divisions, referred to as titles, the most important of which are the following: Title I: Provisions for Attainment and Maintenance of NAAQS, Title II: Provisions Relating to Mobile Sources, Title III: Hazardous Air Pollutants, Title IV: Acid Deposition Control, Title V: Permits, and Title VI: Stratospheric Ozone Protection, Title VII: Provisions Relating to Enforcement, Title VIII: Miscellaneous Provisions, Title IX: Clean Air Research, Title X: Disadvantaged Business Concerns, and Title XI: Clean Air Employment Transition Assistance.

International Nature of the Problem

Air pollution and the problems it causes are not confined by any geopolitical boundaries. For example, the radioactive cloud resulting from the Chernobyl nuclear accident in 1986 traveled as far as Ireland. A United Nations report warns that haze produced by the burning of wood and fossil fuels is creating a two-mile-thick "Asian browncloud" that covers southeastern Asia and may be responsible for hundreds of thousands of respiratory deaths a year.

In the United States, federal pollution laws and regulations apply to all states, even though some states, such as California, have adopted more stringent standards. Similarly, in the European Union (EU) existing laws apply equally to all members. Countries such as Denmark and Germany, however, have elected to imposed stricter standards than those set by the EU.

International agreements aimed at reducing various pollutants have been signed by various countries. The Montreal Protocol was signed in 1987; its purpose is the reduction of chlorofluorocarbons (CFC), a class of compounds that destroy the stratospheric ozone layer. More recently, in 1997, a conference convened in Kyoto, Japan, to discuss ways of reducing carbon

dioxide emissions and other **greenhouse gases**. The United States has not signed the Kyoto Protocol, arguing that such an agreement would impede its economic progress. It has, however, publicly stated its intention to embark on voluntary reductions of carbon dioxide and other greenhouse gases.

greenhouse gas a gas, such as carbon dioxide or methane, which contributes to potential climate change

Air Pollutants

In general, air pollutants are divided into two classes: those for which a NAAQS may be set (in other words, the criteria pollutants), and those for which NAAQS are not appropriate (the HAPs). If the ambient concentration of the criteria pollutants is kept below the NAAQS value, then there will be no health damage due to air pollution. The HAP (mostly known or suspected carcinogens), on the other hand, are those that, even in low concentrations, cause significant damage.

Particulate Matter. Particulate matter (PM) is the term used to describe solid or liquid particles that are airborne and dispersed (i.e., scattered, separated). PM originates from a variety of anthropogenic sources, including diesel trucks, power plants, wood stoves, and industrial processes.

The original NAAQS for PM was set in 1970. In 1987, the total suspended particulate matter, TSP, was revised, and a PM_{10} (particulate matter with an aerodynamic diameter of 10 µm or less) standard was set. PM_{10}, sometimes known as respirable particles, was felt to provide a better correlation of particle concentration with human health.

In 1997 the particulate matter standard was updated, to include the PM2.5 standard. These particles, known as "fine" particles, a significant fraction of which is secondary in nature, are especially detrimental to human health because they can penetrate deep into the lungs. Scientific studies show a link between $PM_{2.5}$ (alone, or combined with other pollutants in the air) and a series of significant health effects, even death.

Fine particles are the major cause of reduced visibility in parts of the United States, including many of the national parks. Also, soils, plants, water, or materials are affected by PM. For example, particles containing nitrogen and sulfur that are deposited as acid rain on land or water bodies may alter the nutrient balance and acidity of those environments so that species composition and buffering capacity change. PM causes soiling and erosion damage to materials, including culturally important objects such as carved monuments and statues.

Carbon Monoxide. Carbon monoxide (CO) is a colorless, odorless, and at high levels a poisonous gas that is fairly unreactive. It is formed when carbon in fuels is not burned completely. The major source of CO is motor vehicle exhaust. In cities, as much as 95 percent of all CO emissions result from vehicular (automobile) emissions. Other sources of CO emissions include industrial processes, nontransportation-related fuel combustion, and natural sources such as wildfires.

CO has serious health effects on humans. An exposure to 50 ppm of CO for eight hours can cause reduced psychomotor performance, while CO is lethal to humans when concentrations exceed approximately 750 ppm. Hemoglobin, the part of blood that carries oxygen to body parts, has an affinity of CO that is about 240 times higher than that for oxygen, forming carboxyhemoglobin, COHb. Moreover, the release of oxygen by hemoglobin is reduced in the presence of COHb. However, the effects of CO poisoning are reversible once the CO source has been removed.

Sulfur Dioxide. Sulfur dioxide (SO_2) is colorless, nonflammable, nonexplosive gas. Almost 90 percent of anthropogenic SO_2 emissions are the result of fossil fuel combustion (mostly coal) in power plants and other stationary sources. A natural source of sulfur oxides is volcanic activities.

In general, exposure to SO_2 irritates the human upper respiratory tract. The most serious air pollution episodes occurred when there was a synergistic effect of SO_2 with PM and water vapor (fog). Because of this, it has proven difficult to isolate the effects of SO_2 alone.

SO_2 is one of the precursors of acid rain (the term used to describe the deposition of acidic substances from the atmosphere). Also, SO_2 is the precursor of secondary fine sulfate particles, which in turn affect human health and reduce visibility. Prolonged exposure to SO_2 and sulfate PM causes serious damage to materials such as marble, limestone, and mortar. The carbonates (e.g., limestone, $CaCO_3$) in these materials are replaced by sulfates (e.g., gypsum, $CaSO_4$) that are water-soluble and may be washed away easily by rain. This results in an eroded surface.

Nitrogen Dioxide. Nitrogen dioxide (NO_2) is a reddish-brown gas. It is a lung irritant and is present in the highest concentrations among other oxides of nitrogen in ambient air. Nitric oxide (NO) and NO_2 are collectively known as NO_x.

Anthropogenic emissions of NO_x come from high-temperature combustion processes, such as those occurring in automobiles and power plants. Natural sources of NO_2 are lightning and various biological processes in soil. The oxides of nitrogen, much like sulfur dioxide, are precursors of acid rain and visibility-reducing fine nitrate particles.

Ozone. Ozone (O_3) is a secondary pollutant and is formed in the atmosphere by the reaction of molecular oxygen, O_2, and atomic oxygen, O, which comes from the photochemical decomposition of NO_2. Volatile organic compounds or VOCs (e.g., what one smells when refuelling the car) must also be present if O_3 is to accumulate in the atmosphere.

O_3 occurs naturally in the stratosphere and provides a protective layer from the sun's ultraviolet rays high above the earth. However, at ground level, O_3 is a lung and eye irritant and can cause asthma attacks, especially in young children or other susceptible individuals. O_3, being a powerful oxidant, also attacks materials and has been found to cause reduced crop yields and stunt tree growth.

Lead. The major sources of lead (Pb) in the atmosphere in the United States are industrial processes from metals smelters. Thirty years ago, the major emissions of Pb resulted from cars burning leaded gasoline. In 2002 only aviation fuels contain relatively large amounts of Pb. The United States is currently working with the World Bank to eliminate the use of leaded gasoline in all countries still using such fuel.

Pb is a toxic metal and can accumulate in the blood, bones, and soft tissues. Even low exposure to Pb can cause mental retardation in children.

Hazardous Air Pollutants. Hazardous air pollutants (HAPs), commonly referred to as air toxics or toxic air pollutants, are pollutants known to cause or suspected of causing cancer or other serious human health effects or damage to the ecosystem.

EPA lists 188 HAPs and regulates sources emitting significant amounts of these identified pollutants. Examples of HAPs are heavy metals (e.g., mercury), volatile chemicals (e.g., benzene), combustion by-products (e.g., dioxins), and solvents (e.g., methylene chloride). HAPs are emitted from many sources, including large stationary industrial facilities (e.g., electric power plants), smaller-area sources (e.g., dry cleaners), mobile sources (e.g., cars), indoor sources (e.g., some building materials and cleaning solvents), and other sources (e.g., wildfires).

Potential human health effects of HAPs include headache, dizziness, nausea, birth defects, and cancer. Environmental effects of HAPs include toxicity to aquatic plants and animals as well as the accumulation of pollutants in the food chain.

Because of the potential serious harmful effects of the HAPs, even at very low concentrations, NAAQS are not appropriate. The EPA has set National Emission Standards for Hazardous Air Pollutants, NESHAP, for only eight of the HAP, including asbestos and vinyl chloride. The EPA regulates HAP by requiring each HAP emission source to meet Maximum Achievable Control Technology (MACT) standards. MACT is defined as "not less stringent than the emission control that is achieved in practice by the best controlled similar source."

Control of Air Pollutants

In general, control of pollutants that are primary in nature, such as SO_2, NO_2, CO, and Pb, is easier than control of pollutants that are either entirely secondary (O_3) or have a significant secondary component ($PM_{2.5}$). Primary pollutants may be controlled at the source. For example, SO_2 is controlled by the use of scrubbers, which are industrial devices that remove SO_2 from the exhaust gases from power plants. SO_2 emissions are also reduced by the use of low-sulfur coal or other fuels, such as natural gas, that contain lower amounts of sulfur. NO_2 from industrial sources also may be minimized by scrubbing. NO_2 from cars, as well as CO, are controlled by the use of catalytic converters, engine design modifications, and the use of cleaner burning grades of gasoline. Lead emissions have been reduced significantly since the introduction of lead-free gasoline.

Ozone and particulate matter are two of the most difficult pollutants to control. Reduction of oxides of nitrogen emissions, together with a reduction of VOC emissions is the primary control strategy for minimizing ozone concentrations. Because a large portion of $PM_{2.5}$ is secondary in nature, its control is achieved by control of SO_2, NO_2, and VOC (which are the precursors of sulfates, nitrates, and carbon-containing particulates). SEE ALSO ACID RAIN; CARBON DIOXIDE; CARBON MONOXIDE; CLEAN AIR ACT; COAL; ELECTRIC POWER; GLOBAL WARMING; GREENHOUSE GASES; LEAD; OZONE; PETROLEUM; TOXIC RELEASE INVENTORY; VEHICULAR POLLUTION.

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Christos Christoforou

Air Pollution Control Act

The Air Pollution Control Act (APCA) of 1955 was the first legislation on air pollution enacted by the U.S. federal government. It resulted after a number of failed attempts, initiated by California's representatives, in the Senate or Congress. Air pollution had long been regarded as a local problem, and the federal government was hesitant to interfere with states' rights. As a result, APCA was rather narrow in scope and effect.

According to the law, the Public Health Service was authorized to spend $3 million per year for five years to research the effects of air pollution and provide technical assistance, research, and training in the area of air pollution to state and local air-quality districts. No money was appropriated for the control of this problem.

APCA was amended in 1960 and then again in 1962, with requests to the Surgeon General to conduct research on the relationship between motor vehicle exhaust and human health. SEE ALSO AIR POLLUTION; LAWS AND REGULATIONS, UNITED STATES.

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Christos Christoforou

Allergies *See Health, Human*

Animal Waste *See Agriculture*

Antinuclear Movement

"I am become death, the shatterer of worlds." Robert Oppenheimer, the "father" of the atomic bomb, muttered these Hindu words after the initial successful test of the new weapon during the summer of 1945. Although Oppenheimer's scientific expertise produced the bomb, he grew increasingly uneasy over its application and destructive power. Oppenheimer became the first of a long line of antinuclear activists and scientists to protest nuclear weapons and nuclear power.

In the early 1950s, the United States began testing an even more powerful nuclear weapon, the hydrogen bomb, in Nevada and the islands of the South Pacific. This testing came in the wake of the cold war, a struggle for power and survival between the United States and the Soviet Union following

Police wearing riot gear form a human barricade against antinuclear demonstrators in Germany, May 7, 1996. (© Regis Bossu/Corbis Sygma. Reproduced by permission.)

World War II. With the Soviet Union's development of its own atomic bomb in 1949, American policymakers became increasingly concerned that such a weapon could be aimed at the United States, and pressed for more powerful nuclear weapons. A thousand times more powerful than the bombs dropped on Hiroshima and Nagasaki to end World War II, the hydrogen bomb also showered huge amounts of radioactive elements, called *fallout*, into the atmosphere. This debris affected the entire globe, falling with precipitation, and entering the food chain when absorbed by plants and eaten by animals like cows and humans.

As concern mounted, citizens formed groups to protest. In 1957 the Committee for a Sane Nuclear Policy (SANE) began pressing for a halt to weapons testing, with the help of prominent Americans like publisher Norman Cousins and child-care expert Dr. Benjamin Spock. Women also played an important role in this early antinuclear activism. Alarmed by prospective dangers to their children, a group called Women Strike for Peace (WSP) organized a nationwide protest against nuclear testing and radiation on November 1, 1961. In New York City, for example, WSP supporters marched outside the United Nations building. Antinuclear activists continued to pressure politicians, resulting in the 1962 ratification of the American-Soviet treaty banning nuclear weapons tests in the atmosphere, space, and underwater.

The late 1960s through 1980s saw a shift in the antinuclear movement toward protesting the development of nuclear power as an energy source. Although the government, through the Atomic Energy Commission (AEC),

had advocated for peaceful uses of nuclear power since the development of the atomic bomb, little impetus existed for new energy sources. With the energy crisis of the 1970s and increased public awareness of the environmental problems engendered by fossil fuels, the government pressed forward with the development of several nuclear power plants, ostensibly to reduce American dependence on oil and provide cheap sources of electricity.

Several citizens' groups emerged to confront nuclear power issues, raising concerns about adequate safety plans and the long-term effects of low-level radiation. Chief among these were the Clamshell Alliance and the Abalone Alliance. A coalition of New England activists formed the Clamshell Alliance in 1976. Using civil rights protest methods, it organized the sit-in of thousands at the Seabrook power plant in New Hampshire, beginning in August 1976 and continuing through early 1977. The Abalone Alliance mobilized pacifists and environmental activists in a protest against the Diablo Canyon nuclear power plant in California. More citizens joined these types of organizations after the 1978 release of *The China Syndrome*, a film depicting a near-disaster at a nuclear power plant. A real accident, strangely similar to the event presented in the film, occurred the following year at the Three Mile Island nuclear power plant in Pennsylvania and caused the evacuation of thousands of people from their homes out of fear of radioactive contamination. A far more destructive nuclear power plant accident occurred in the Ukraine in 1986 at Chernobyl. In this catastrophe, radioactive waste spewed from a reactor explosion, and over 130,000 people were forced to leave the area. The contamination greatly increased many of their chances of developing cancer.

The antinuclear movement succeeded in virtually halting the governments' development of nuclear power, and also influenced further nuclear weapons reductions, especially as the Cold War began to wind down by the late 1980s. Government officials, however, continued to search for ways to deal with the problem of the radioactive waste produced by the nuclear power plants. Despite citizen concern in the 1990s over the inherent dangers of transporting nuclear waste, over the summer of 2002, President George W. Bush authorized the development of a site at Yucca Mountain, a hundred miles outside of Las Vegas, to store nuclear waste. Scheduled to open in 2010, the Yucca Mountain site will store, in one place, waste that is currently scattered around the country. Also during the 1990s, increased information about radiation's health hazards led to the Radiation Exposure Compensation Act of 1990, which attempted to compensate some of the cancer victims of 1950s nuclear testing.

Renewed concerns about nuclear power plants have also surfaced in the wake of the terrorist attacks in the United States on September 11, 2001. With rumors of possible terrorist attacks on nuclear power stations, access to plans and information has become more limited. The Yucca Mountain Web site, for example, removed the plans for its facility in the hopes of preventing terrorist attacks. SEE ALSO Activism; Industry; Politics; Public Participation; Radioactive Fallout; Radioactive Waste.

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Elizabeth D. Blum

Aquifers *See Water Pollution: Freshwater*

Arbitration

Arbitration is a process in which disputing parties abandon their right to litigate or appeal to the judicial court and instead put their case before an impartial third party who renders an opinion or recommendation. If the arbitration is nonbinding, the parties may choose to accept it or not. If it is binding, the parties must abide by the decision, which has the force of law and can be enforced. Parties may voluntarily submit to arbitration rather than incur the costs of litigation. Courts may also force parties to go to arbitration. Examples of cases that have gone to arbitration concern the location of gas pipelines and liability for paying for pollution cleanup. SEE ALSO CONSENSUS BUILDING; ENFORCEMENT; LITIGATION; MEDIATION; PUBLIC POLICY DECISION MAKING; REGULATORY NEGOTIATION.

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Susan L. Senecah

Arctic National Wildlife Refuge

The Arctic National Wildlife Range was established in 1960 to conserve 8.9 million acres of Alaska's remote northeast corner. This roadless area, north of the Arctic Circle, consists of arctic and alpine tundra, coastal lagoons and barrier islands, and **boreal** forest. It stretches along 110 miles of the Beaufort Sea (part of the Arctic Ocean) to the border with Canada's Yukon Territory. The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 increased the size of the refuge to nineteen million acres (about the size of South Carolina) and renamed it the Arctic National Wildlife Refuge (ANWR). Together with the adjacent Ivvavik and Vuntut National Parks in Canada, it comprises the second-largest international conservation area in North America (after the Wrangell-St. Elias and Glacier Bay National Parks in Alaska and the neighboring Tatshenshini-Alsek and Kluane Parks in Canada) and one of the largest protected natural areas in the world.

boreal northern, subarctic

To win passage of ANILCA, President Jimmy Carter compromised with Congress and left open the possibility of future oil and gas development in 1.5 million acres of ANWR's coastal plain in what was called the 1002 Area. Such exploitation would require an act of Congress. Ever since, this has been

one of the most contentious environmental issues facing Congress, pitting prodevelopment legislators (primarily Republicans) against conservationists (primarily Democrats). For example, in 2002 the Bush administration advocated legislation to open the refuge to oil exploration, but this legislation was defeated by the Senate under Democratic control.

drilling waste material (soil, ground rock, etc.) removed during drilling

Oil companies argue that they can drill for oil in ANWR with minimal environmental damage. New technologies such as directional drilling allow for multiple wellheads on a minimal "footprint." In ANWR, this means that the oil deposits could be exploited from an area about the size of a large airport. **Drilling waste** can be reinjected deep under ground in porous rock formations. Three-dimensional seismic surveys provide more accurate data about the location of oil reserves, and thereby reduce the number of dry holes. Oil companies contend that work can be completed during winter months on temporary roads and drilling pads built out of ice that simply melts away in the summer. The industry argues that drilling in ANWR would reduce U.S. reliance on foreign oil and prices at the pump. Furthermore, oil development would bring tax revenues to the state of Alaska and the national government. Many Inupiat Eskimos in the coastal plain of the refuge favor oil development for the economic boom it will bring them, although they oppose drilling offshore where they hunt whales.

Conservationists argue that 95 percent of Alaska's North Slope is already open to oil development. The U.S. Geological Survey has estimated that ANWR likely holds enough oil to supply six months of U.S. consumption, and that these reserves would take ten years to develop. Conservationists point out that the United States could easily save more oil than can be extracted from ANWR by increasing automobile fuel efficiency standards. For example, a one-mile per gallon increase in U.S. automobile fuel efficiency for a thirty-year period would save more oil than the projected yield from ANWR. The refuge would not significantly decrease U.S. dependence on foreign oil or reduce pump prices: Even with ANWR oil, the United States possesses only 3 percent of the world's known oil reserves, but consumes 25 percent of world production. Oil in ANWR is thought to exist in several pockets, necessitating an industrial infrastructure of roads, pipelines, drill sites, processing facilities, power plants, utility lines, water reservoirs, airstrips, helicopter pads, gravel mines, landfills, equipment sheds, and living quarters that would fragment the landscape like a net, even though the drilling platforms themselves would not cover a large area. Ice roads and pads would require introducing a great deal of water into the desertlike coastal plain, while drawing that water from surface ponds and lakes could lower water levels enough to lead to complete freezing in winter, killing resident fish populations. The U.S. Fish and Wildlife Service estimates that the 1002 Area has only enough usable water for ten miles of ice roads, necessitating the construction of permanent gravel roads.

The refuge's harsh climate leads to short growing seasons and slow life processes, which in turn make it vulnerable to human disturbance, including oil spills. Conservationists stress that in the nearby Prudhoe Bay oil field the industry reports an average of more than one spill of oil products or other hazardous substances per day. Large spills from the 800-mile Trans-Alaska Pipeline occur occasionally, as happened in 2001 when a man shot a bullet through the pipeline, causing a 285,000 gallon spill.

ANWR is home to the greatest diversity of wildlife of any protected ecosystem in the Arctic, including forty-five species of land mammals and about 180 species of birds. Although one of the most isolated natural areas in the world, the refuge is ecologically connected to most of the continents and to every U.S. state except Hawaii by more than 130 species of migrating birds that nest or feed on the refuge. The greatest concentration of pregnant polar bears denning on land in Alaska occurs in the 1002 Area, and this area is also the most important calving area for the Porcupine caribou herd, the world's largest international migratory herd, which in 2001 numbered about 130,000 animals. Every year the herd migrates 800 miles round-trip from its calving grounds in ANWR to the adjacent Ivvavik and Vuntut National Parks in Canada, where industrial activity is banned. The caribou provide subsistence to the Gwich'in Indians along the migratory route. The Gwich'in, whose name means "people of the caribou," oppose drilling in ANWR because they believe it would ruin their traditional way of life. For them the coastal plain is sacred. The Gwich'in are supported by the majority of Americans, who over the years have consistently favored conserving the coastal plain from oil development. The League of Conservation Voters commissioned Democratic and Republican polling firms in May 2001 to survey 1,000 Americans; they found that 62 percent opposed drilling in the refuge while 34 percent favored it. SEE ALSO PETROLEUM.

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Frank A. von Hippel

Arsenic

Arsenic (As) is a naturally occurring element that has been used in a variety of applications—in pesticides, as wood preservatives, and as a treatment for syphilis. Throughout history, arsenic was the most often used poison. Some historians believe that Nero used arsenic to poison Claudius in 54 C.E. Arsenic has also been the poison of choice in murder mysteries due to its easy availability in rat poison and insecticides.

In its elemental form, arsenic is a steel gray metal-like material. Combined with carbon and hydrogen, it forms organic arsenic compounds. When combined with oxygen, chloride, and sulfur, it forms inorganic arsenic compounds. Organic arsenic is generally less toxic than inorganic arsenic. Chromated copper arsenate (CCA), a pesticidal compound, has been widely used as a wood preservative. In February 2002 industry announced a voluntary decision to remove arsenic-treated lumber products (play structures, picnic tables, deck wood, etc.) from the market. By January 2004 the Environmental Protection Agency (EPA) will no longer allow CCA products for residential use. Although the EPA has not concluded that arsenic-treated wood poses an "unreasonable risk" to the public, arsenic is a known human carcinogen and any decrease in exposure from any source is desirable. Over 100,000 tons of arsenic are produced worldwide, most of which is a by-product of the **smelting** of metals such as copper and lead.

smelting the process in which a facility melts or fuses ore, often with an accompanying chemical change, to separate its metal content; emissions cause pollution

Arsenic occurs naturally in soils, rocks, water, and air. The burning of high-arsenic coal, the use of arsenical pesticides, and metals manufacturing has redistributed arsenic throughout the environment. Human exposure to arsenic occurs through ingestion of water and food contaminated with arsenic or the inhalation of contaminated air. The greatest human exposure to arsenic is through consumption of contaminated seafood. However, the arsenic in seafood is organic arsenic, which is low in toxicity. **Ingestion** of inorganic arsenic in drinking water represents the greatest health hazard.

ingest take in through the mouth

Ingestion of large amounts of inorganic arsenic is extremely toxic and can be fatal. Although environmental levels of arsenic are much lower, exposure to arsenic in drinking water has been associated with increased risks of cancer of the bladder, kidney, skin, and lung. Noncarcinogenic effects include lesions of the skin; *blackfoot disease*, a peripheral vascular disorder; cardiovascular and neurological diseases; and possible adverse effects on the reproductive system. Recent research has shown arsenic to be an endocrine disruptor, blocking a steroid that regulates a number of biological processes.

Arsenic contamination of drinking water supplies is a worldwide problem. Areas where drinking water is of specific concern include Bangladesh, India, Hungary, Chile, China, Argentina, Taiwan, Ghana, Mexico, the Philippines, New Zealand, and the United States (primarily the western states). The World Health Organization (WHO) has established a guideline of 10 micrograms (µg) of arsenic per liter, or ten parts per billion (ppb), in drinking water. In February 2002 the EPA announced the new arsenic drinking water standard of ten ppb. By 2006 community drinking water systems across the United States must be in compliance. There are several methods to removing arsenic from drinking water, including:

- *Coprecipitation*, where iron binds with arsenic and the particles settle out or are removed.
- *Adsorption*, where arsenic adheres to aluminum or iron and can be removed.
- *Membrane filtration*, where arsenic is filtered out of the water.
- *Ion exchange*, where a chemical process exchanges chloride for arsenic.

The estimated cost for compliance of the new arsenic drinking water standard in the United States is approximately $177 million per year. The average cost per household is dependent upon the size of the community water system—the smaller the system, the higher the cost.

Arsenic has also been identified in hazardous waste sites within the United States. Scientists at the University of Florida's Institute of Food and Agriculture Sciences have identified the brake fern, *Pteris vittata*, which absorbs arsenic from the soil. The potential use of this fern to clean up arsenic from such sites is called *phytoremediation*, where plants and trees are used to extract contaminates from the soil. Many arsenic compounds dissolve in water, and thus, the cleanup of these waste sites would protect the underlying aquifers. SEE ALSO Bioremediation; Endocrine Disruption; Health, Human; Risk; Smelting; Water Treatment.

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Betsy T. Kagey

Asbestos

Asbestos is a mineral rock with a chemical composition of mostly silicon, water, and magnesium. Most asbestos fibers are long, thin, strong, flexible, fireproof, and resistant to chemical attack. Of the six varieties of asbestos fibers found in nature, only three are commonly found in construction materials: chrysotile, amosite, and crocidolite. Chrysotile, the variety most often found in building materials, absorbs water readily, which allows for easier removal. Chrysotile was commonly used as a binding and strengthening agent in plastics, cement, and insulation. Extremely long chrysotile fibers were woven into fire- and heat-resistant cloth.

Asbestos is a **carcinogen**, and medical reports indicate a single fiber can cause lung cancer. There is little health risk if the material is fully intact and is properly maintained; but it can quickly turn dangerous if any of the fibers become **friable** and airborne, and are inhaled.

carcinogen any substance that can cause or aggravate cancer

friable capable of being crumbled, pulverized, or reduced to powder by hand pressure

Asbestos has been used in a wide variety of products and materials. Its positive properties of heat and chemical resistance were discovered early in history: Egyptians wove asbestos fibers into cremation shrouds and the Greeks made lamps with "inextinguishable" wicks of asbestos. Asbestos fibers have been used in approximately 3,000 different applications. At asbestos's commercial peak, the United States used nearly one million tons of asbestos per year. Common asbestos-containing materials (ACM) include thermal and acoustic insulation, fireproofing, concrete, flooring, roofing felts, building papers, shingles, electrical insulation, decorative sprays, gaskets, packing, and textiles.

The principal sources of airborne asbestos fibers are the quarrying, mining, milling, manufacturing, and application of asbestos products. Medical reports have documented laboratory and clinical evidence that inhalation of asbestos fibers can lead to an increased risk of developing **asbestosis**, lung cancer, and **mesothelioma**. Epidemiological studies also show that the risk of lung cancer increases tenfold for smokers compared to nonsmokers exposed to asbestos. In the past, the individuals at greatest risk of developing these diseases were asbestos workers who were exposed to high concentrations of asbestos fibers each working day with virtually no respiratory protection. The combination of cautionary medical reports and a better-informed public spurred the U.S. Environmental Protection Agency (EPA) to begin banning the manufacture of asbestos-containing products in the early 1970s.

asbestosis a disease associated with inhalation of asbestos fibers; the disease makes breathing progressively more difficult and can be fatal

mesothelioma malignant tumor of the mesothelium, a cell layer within the lungs and other body cavities

The mineral vermiculite, mined in the United States and elsewhere, is also used as insulation and can be, though is not always, contaminated with asbestos. Asbestos-contaminated vermiculite mined in Libby, Montana, from 1963 to 1990 has caused hundreds of mine workers and family members in Libby to become sick or die from asbestos-related disease. According to the

ASBESTOSIS: YEARS OF POTENTIAL LIFE LOST BY RACE AND GENDER, U.S. RESIDENTS AGE 15 AND OVER, 1991–1992

		White		Black	
Year	Overall	Males	Females	Males	Females
		Years of potential life lost to age 65			
1991	1,015	845	30	130	0
1992	890	780	15	50	30
		Years of potential life lost to life expectancy			
1991	11,883	9,294	466	664	28
1992	11,850	9,441	389	540	80

SOURCE: Adapted from National Center for Health Statistics multiple cause of death data.

EPA, about 70 percent of the vermiculite mined worldwide came from the Libby mine and most was sold as zonolite attic insulation between 1963 and 1984. The EPA recommends that vermiculite insulation in homes be tested for asbestos.

The EPA regulates environmental exposure to asbestos while the Occupational Safety and Health Administration (OSHA) regulates occupational exposure to asbestos. The most recent EPA regulation is the Asbestos Hazard Emergency Response Act (AHERA) for schools. This regulation became effective in 1987 and specifically outlines inspection, reinspection, periodic surveillance, and management plans for all schools to minimize exposure to asbestos. This regulation was considered state-of-the-art when it first came out and it soon became applicable to all public and private buildings.

The asbestos workers of today wear high-efficiency respirators and protective clothing to minimize the risk of developing one of the asbestos diseases. OSHA limits a worker's exposure (over an eight-hour, time-weighted average) to no more than 0.2 fibers per cubic centimeter. In the last fifteen years, asbestos regulations have been put into effect, prompting the need for asbestos abatement policies.

The current policies on asbestos are centered on the protection of the building occupants and maintenance and repair personnel. Many building occupants believe that any ACM must be removed immediately. In some cases, this is a reasonable choice, but in most situations, immediate removal is not required. To deal with an asbestos material in any building requires planning and continuous management. Improper removal can increase asbestos-related health risks significantly.

The first step in developing an effective long-term asbestos management program involves defining the nature and scope of the problem. This requires a complete building survey, including a walk-through of the entire building to include basements, crawl spaces, and attics. Bulk samples of suspected ACM material should be taken, including wallboard, insulation, roofing, floor tile, mastic, fireproofing, plaster, concrete, mortar, sprayed-on ceiling and ceiling panels, exterior siding, and fire doors. The bulk samples of each suspect material should then be analyzed by a certified/accredited laboratory, and a management plan should be developed.

The EPA endorses ACM management and recently released a regulation that endorses management versus blanket removal. An operations and maintenance (O&M) program describes the steps to maintain ACM in a building to minimize exposure to airborne asbestos fibers, and to prevent uncontrolled disturbance of ACM. It describes what must be removed, what ACM is repairable, how repairs are performed, and how remaining ACM is maintained and/or repaired. Any ACM that must be removed from a building for offsite disposal will be subject to waste transportation and disposal regulations. Most states require haulers to have waste-transportation permits. Friable asbestos is considered a hazardous substance under the Federal Superfund Law, and therefore requires special handling.

Building surveys should be an automatic requirement for any building erected before 1985. Recently, a city in northern California leased an existing movie theater with the intention of renovating it for use as a performing arts theater. Shortly before work was to begin, ACMs were identified in many portions of the facility. The city council was extremely surprised by the presence of asbestos in the building, even though the building was built in 1950. There was no asbestos survey conducted prior to the commencement of the renovation, and the building owner had verbally assured the council that the presence of ACMs was highly unlikely. The project continued, but at substantial, and unexpected, additional expense and delay. Building identification surveys are being conducted by most building owners who want to prevent any costly confrontations with ACMs. The Army Corps of Engineers in Sacramento requires an identification survey for any building that is scheduled for demolition or remodel. These surveys have indicated that mastic, boiler refractory, flexible duct connectors, silver (heat-resistant) paint, and wall taping compound can also contain asbestos and must be tested. Each asbestos identification survey has taught the Corps of Engineers new precautions to take when conducting the next one.

All building owners need to have asbestos identified and located, and its condition recorded. An operation and maintenance plan needs to be developed for each building, and maintenance workers need to be educated before they come in contact with asbestos. Legislative and public attention has led to the requirement of a long-term approach aimed at ensuring the safety of those who come into contact with asbestos. SEE ALSO Cancer; Health, Human.

Internet Resource

Agency for Toxic Substances and Disease Registry Asbestos pages. Available from http://www.atsdr.cdc.gov/ToxProfiles/phs9004.html and http://www.atsdr.cdc.gov/HEC/CSEM/asbestos/who's_at_risk.html.

EPA's Asbestos and Vemiculite homepage. Available from http://www.epa.gov/asbestos.

National Institute for Occupational Safety and Health Asbestos topic page. Available from http://www.cdc.gov/niosh/topics/asbestos.

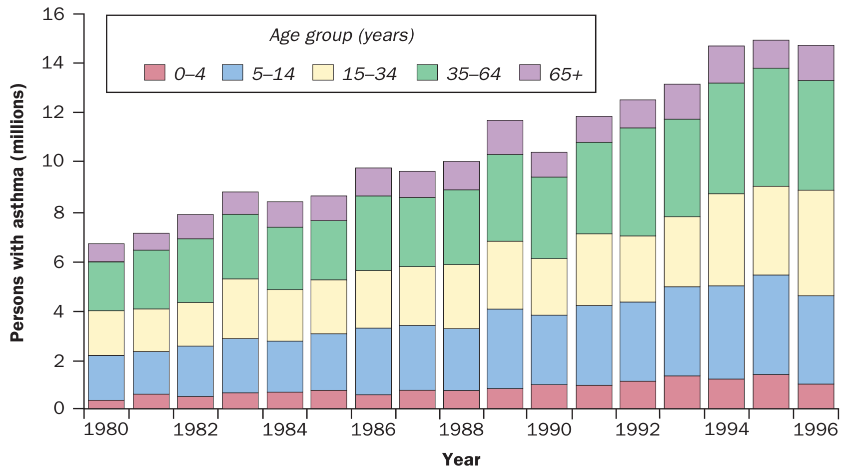
OSHA Web site. Asbestos information pages. Available from http://www.osha-slc.gov/SLTC.

Linda N. Finley-Miller

Asthma

Asthma is a chronic disease of the lungs that affects millions around the world, particularly in industrialized countries. The symptoms of asthma

NUMBER OF PERSONS WITH ASTHMA IN THE UNITED STATES: NATIONAL HEALTH INTERVIEW SURVEY, 1980–1996



include shortness of breath, chest tightness, wheezing, and coughing; nighttime symptoms that interfere with sleep can be particularly troublesome. These symptoms are caused by inflammation, swelling, and constriction of muscles that surround the breathing tubes in the chest, the airways connecting the lungs to the mouth and nose. The hallmark of asthma is variability and reversibility in the inflammation and constriction of the airways.

Although researchers have identified a number of chemicals in the workplace that can cause asthma, the cause of most cases of asthma is unknown. Genetic risk factors are important; adults who have asthma are more likely to produce children with asthma than adults who do not suffer from this ailment. Genetic risk cannot explain the increase in the number of persons with asthma in the United States, from 6.8 million persons in 1980 to about 15 million in 1996, because the genetic composition of the population changes much more slowly than that.

Whether outdoor air pollution might cause asthma has not been sufficiently studied. Although many people are afflicted with asthma, determining exactly when an individual's disease began—so the critical period of environmental exposures might be identified—is difficult. Studies comparing the overall rate of asthma with air pollution levels have not produced data showing a relationship between asthma and outdoor pollution. For example, increases in the number of persons with asthma in the United States occurred while the overall levels of outdoor air pollution were declining. Despite the overall decline in air pollution, concentrations of ozone and airborne particles with a diameter less than 10 microns (abbreviated as PM_{10}) have hardly declined at all. Nevertheless, these trends do not implicate outdoor air pollution as an important cause of the increase in asthma sufferers. Information comparing rates of asthma among children born in Germany before and after reunification in 1989 also do not support a role for air pollution in causing asthma. Air pollution from industrial sources was greater in the former East Germany than in West Germany, yet the situation with asthma was the reverse, with a higher rate of asthma present in West Germany. The difference

in asthma rates appeared to result from higher rates of allergy in West Germany. In contrast to these studies, one recent study conducted in southern California found an increased risk for developing asthma in children who participated in team sports, a surrogate for greater exposure, and who also lived in areas with higher ozone levels.

Some outdoor air pollutants, such as ground-level ozone, PM_{10}, sulfur dioxide, and nitrogen oxides, can worsen asthma. Related studies compare the rate of emergency department visits for asthma at times of high levels of air pollution with such visits at times of low levels of air pollution. In a study conducted during the 1996 Olympics in Atlanta, changes in traffic patterns were associated with reduced levels of ozone and with fewer emergency department visits for asthma.

Indoor air pollution probably plays a more significant role in asthma than outdoor air pollution. On average, people spend much more time indoors than outdoors, and concentrations of some pollutants can be many times higher indoors. Indoor air exposures are classified as being biological, derived from living organisms, or chemical. Because no regulations exist for levels of indoor air pollutants, concentrations of these exposures are not measured with the same frequency and uniformity as those for outdoor pollutants.

Among indoor exposures, exposure to house dust mites has been found to cause asthma and, for preschool-aged children, environmental tobacco smoke has been associated with the development of asthma. Some evidence exists that exposure to cockroaches and infection with respiratory syncytial virus also may be linked to the development of asthma. Researchers have correspondingly identified a much longer list of indoor exposures that can trigger or worsen asthma: besides the above factors, exposure to cat dander, molds, dogs, and nitrogen oxides.

An individual can take many steps to reduce exposure to the factors that exacerbate asthma. Basic precautions include the following: Stop smoking and avoid tobacco smoke; vacuum the home once or twice a week (but with the asthma-affected person not present); avoid mold, making sure that moisture collections are addressed to prevent mold growth; and reduce exposure to house dust mites, cats, dogs, and cockroaches, depending on which of these are allergic triggers for the asthma sufferer.

The importance of air pollution, whether indoor or outdoor, as a cause of asthma remains a subject of intense study. Exposure to house dust mites appears to be capable of causing asthma and environmental tobacco smoke has been associated with the development of asthma, but evidence linking these exposures to the increase in asthma cases is lacking. SEE ALSO AIR POLLUTION; HEALTH, HUMAN; INDOOR AIR POLLUTION.

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Stephen C. Redd

B

Automobiles *See Vehicular Pollution*

Beach Washups *See Medical Waste; Water Pollution: Marine*

Beneficial Use

Beneficial use is the productive use of water or solid material that is normally discarded or disposed of in a landfill or burned.

Throughout the years, more materials that have been disposed of in the past are finding new demands and uses. Economics have shifted to make these products more valuable for beneficial use. The U.S. environmental laws and regulations in the 1970s established national policies to search for ways to recycle society's discarded products. The National Resource Recovery Act of 1975 and the Clean Water Act of 1972 set goals for the beneficial use of solid waste, wastewater, and **biosolids**, and the National Environment Policy Act of 1969 required public agencies to include beneficial use in decision making.

biosolid solid or semisolid waste remaining from the treatment of sewage

Wastewater from treatment plants is becoming more valuable in water-short areas of the country such as California. It is used for the irrigation of agricultural crops or residential landscaping as an alternative to the use of water that is normally reserved for drinking. Biosolids are being recycled as an alternative to commercial fertilizers. Used soda bottles are turned into fence posts and clothing. Dredge spoils are no longer disposed of in deep-water areas, but instead are used as a resource for a variety of beneficial purposes, including beach nourishment, construction fill, landscaping, and landfill cover. SEE ALSO BIOSOLIDS; DREDGING.

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Peter S. Machno

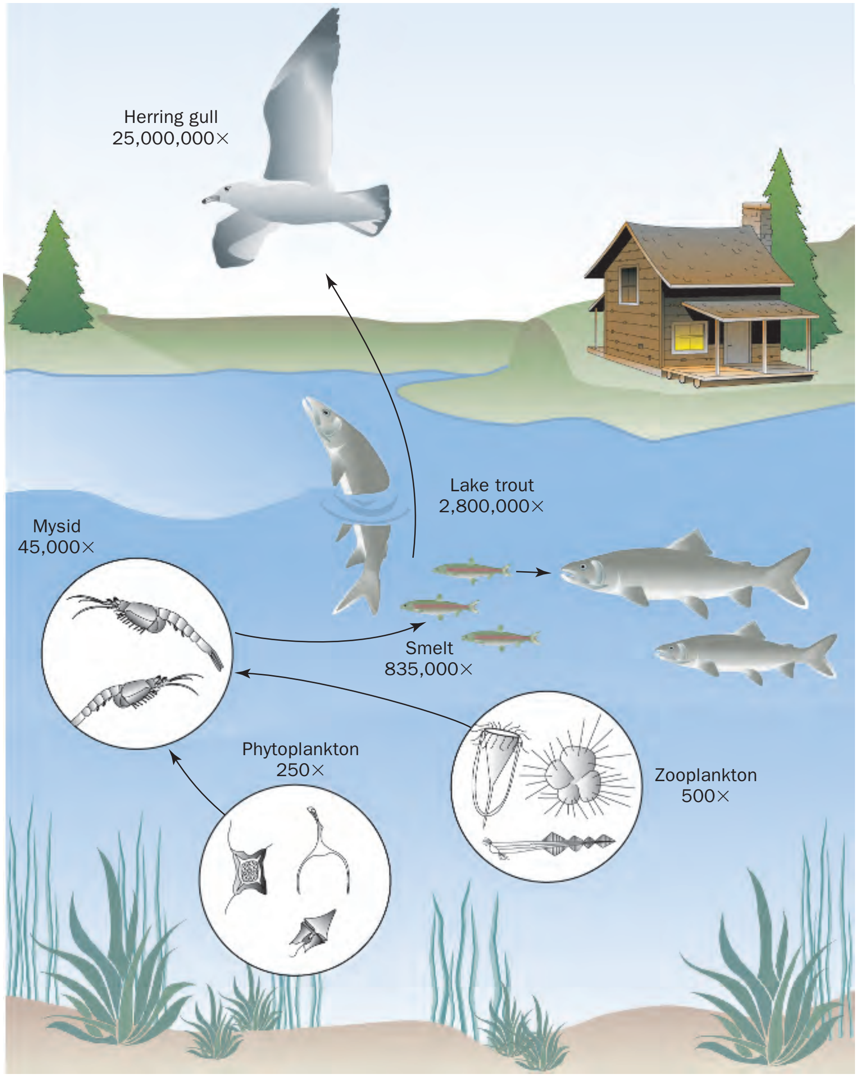
Benefit-cost Analysis *See Cost-benefit Analysis*

Bioaccumulation

Bioaccumulation is the accumulation of contaminants by species in concentrations that are orders of magnitude higher than in the surrounding environment.

Bioaccumulation is the sum of two processes: bioconcentration and biomagnification. Bioconcentration is the direct uptake of a substance by a living organism from the medium (e.g., water) via skin, gills, or lungs, whereas biomagnification results from dietary uptake. Many synthetic contaminants are more soluble in fat than in water. Polychlorinated biphenyls (PCBs), for example, which can be present in lake or river water, tend to either adsorb to particles or to diffuse into cells of organisms. Thus, PCBs bioconcentrate in low trophic levels, for example, in phytoplankton by a factor of around 250. Fish that actively filter large amounts of water through their gills are subject to a much higher bioconcentration. Additionally, biomagnification takes place in predatory organisms. The PCB burden of the prey is transferred to the predator. Fish like smelt that consume large quantities of mysids and

LAKE ONTARIO BIOMAGNIFICATION OF PCBs



zooplankton magnify the PCB concentration. This leads to bioaccumulation factors as high as 2.8 million in predatory fish species such as lake trout and striped bass. Mammals—including humans that eat the fish, reptiles, and birds—further accumulate PCBs.

Finally, in the leading predators among marine life—the seal and polar bear—PCBs and other persistent organic pollutants (POPs) reach concentrations that cause obvious impairments of the immune and reproductive system. A significant proportion of these accumulated contaminants is transferred to the offspring by the mother's milk, resulting in, for example, abnormal sexual development, behavioral dysfunctions, and cancer. Prerequisites for a substance's strong bioaccumulation are its affinity for fat and low biodegradability, or persistence in the environment. Bioaccumulating contaminants thus far identified are the first-generation organochlorine pesticides (e.g., DDT, chlordane, and toxaphene), PCBs, dioxins, brominated flame retardants, but also

some organo-metal compounds, for example, methyl mercury and tributyltin (TBT). Because of their strong bioaccumulation and toxicity, some of these substances were banned in North America and Western Europe after 1970. The bioconcentration factor (BCF) often serves as a trigger for the hazard classification of chemicals. In the European Union a BCF greater than one hundred leads to a substance's classification as "dangerous to the environment." The U.S. Environmental Protection Agency (EPA) uses a BCF of greater than 1,000 for environmentally harmful substances. In Canada chemicals with a BCF greater than 5,000 are recommended for "virtual elimination." SEE ALSO DDT (DICHLORODIPHENYL TRICHLOROETHANE); MERCURY; PCBS (POLYCHLORINATED BIPHENYLS); PERSISTENT BIOACCUMULATIVE AND TOXIC (PBT) CHEMICALS; PERSISTENT ORGANIC POLLUTANTS (POPS); PESTICIDES.

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Stefan Weigel

Biodegradation

Biodegradation is the decay or breakdown of materials that occurs when microorganisms use an organic substance as a source of carbon and energy. For example, sewage flows to the wastewater treatment plant where many of the organic compounds are broken down; some compounds are simply biotransformed (changed), others are completely **mineralized**. These biodegradation processes are essential to recycle wastes so that the elements in them can be used again. Recalcitrant materials, which are hard to break down, may enter the environment as contaminants.

mineralize convert to a mineral substance

Biodegradation is a microbial process that occurs when all of the nutrients and physical conditions involved are suitable for growth. Temperature is an important variable; keeping a substance frozen can prevent biodegradation. Most biodegradation occurs at temperatures between 10 and 35°C. Water is essential for biodegradation. To prevent the biodegradation of cereal grains in storage, they must be kept dry. Foods such as bread or fruit will support the growth of mold if the moisture level is high enough. The microorganisms need energy plus carbon, nitrogen, oxygen, phosphorus, sulfur, calcium, magnesium, and several metals to grow and reproduce. The oxidation of organic substances to carbon dioxide and water is an exothermic (heat-releasing) process. For each **mole** of oxygen used as electron acceptor (oxidant), about 104 kilocalories (435 kJ) of energy is potentially available. All organisms make use of only part of this energy. The rest is lost as heat. This can be seen in composting when the compost becomes hot. Biodegradation

mole a chemical quantity, 6×10^{23} molecules. For oxygen, this amounts to 32 grams

can occur under aerobic conditions where oxygen is the electron acceptor and under anaerobic conditions where nitrate, sulfate, or another compound is the electron acceptor.

Bacteria and fungi, including yeasts and molds, are the microorganisms responsible for biodegradation. Environmental managers want to use biodegradation when it is needed and prevent it when preservation is important. Chemicals are commonly used to treat wood in buildings and other structures to prevent biodegradation. Wooden posts and pilings are treated with creosote or copper compounds to prevent rotting. Compounds that inhibit biodegradation are often added to automobile antifreeze solutions, aircraft **deicer** formulations, and other products to preserve the original qualities of the product. These products and chemicals can enter the environment and become contaminants. The inhibitors have a negative effect when the product becomes a waste and is to be biodegraded. For example, biodegradation of aircraft deicer formulations in airport runoff is often inhibited because of the benzotriazoles that are present to preserve the formulation. SEE ALSO BIOREMEDIATION; SOLID WASTE.

deicer chemical used to melt ice

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Larry Eugene Erickson and Lawrence C. Davis

Biohazard *See Medical Waste*

Biological Control *See Agriculture; Pesticides*

Bioremediation

Bioremediation means to use a biological remedy to abate or clean up contamination. This makes it different from remedies where contaminated soil or water is removed for chemical treatment or decontamination, incineration, or burial in a landfill. Microbes are often used to remedy environmental problems found in soil, water, and sediments. Plants have also been used to assist bioremediation processes. This is called phytoremediation. Biological processes have been used for some inorganic materials, like metals, to lower radioactivity and to remediate organic contaminants. With metal contamination the usual challenge is to accumulate the metal into harvestable plant parts, which must then be disposed of in a hazardous waste landfill before or after incineration to reduce the plant to ash. Two exceptions are mercury and selenium, which can be released as volatile elements directly from plants to atmosphere. The concept and practice of using plants and **microorganisms** to remediate contaminated soil have developed over the past thirty years.

microorganism bacteria, archaea, and many protists; single-celled organisms too small to see with the naked eye

The idea of bioremediation has become popular with the onset of the twenty-first century. In principle, genetically engineered plants and microor-

ESSENTIAL FACTORS FOR MICROBIAL BIOREMEDIATION

Factor	Desired Conditions
Microbial population	Suitable kinds of organisms that can biodegrade all of the contaminants
Oxygen	Enough to support aerobic biodegradation (about 2% oxygen in the gas phase or 0.4 mg/liter in the soil water)
Water	Soil moisture should be from 50–70% of the water holding capacity of the soil
Nutrients	Nitrogen, phosphorus, sulfur, and other nutrients to support good microbial growth
Temperature	Appropriate temperatures for microbial growth (0–40°C)
pH	Best range is from 6.5 to 7.5

ganisms can greatly enhance the potential range of bioremediation. For example, bacterial enzymes engineered into plants can speed up the breakdown of TNT and other explosives. With transgenic poplar trees carrying a bacterial gene, methyl mercury may be converted to elemental mercury, which is released to the atmosphere at extreme dilution. However, concern about release of such organisms into the environment has limited actual field applications.

Natural Bioremediation

Natural bioremediation has been occurring for millions of years. Biodegradation of dead vegetation and dead animals is a kind of bioremediation. It is a natural part of the carbon, nitrogen, and sulfur cycles. Chemical energy present in waste materials is used by microorganisms to grow while they convert organic carbon and hydrogen to carbon dioxide and water.

Managed Bioremediation

When bioremediation is applied by people, microbial biodegradation processes are said to be managed. However, bioremediation takes place naturally and often it occurs prior to efforts to manage the process. One of the first examples of managed bioremediation was land farming (refers to the managed biodegradation of organic compounds that are distributed onto the soil surface, fertilized, and then tilled). Many petroleum companies have used it. High-molecular-weight organic compounds (i.e., oil sludges and wastes) are spread onto soil and then tilled into the ground with fertilizer, as part of the managed bioremediation process. Good conditions for microbial biodegradation are maintained by controlling soil moisture and soil nutrients. In 1974 R.L. Raymond was awarded a patent for the bioremediation of gasoline. This was one of the first patents granted for a bioremediation process.

Since about 1980, prepared bed systems have been used for bioremediation. In this approach, contaminated soil is excavated and deposited with appropriate fertilizers into a shallow layer over an **impermeable** base. Conditions are managed to obtain biodegradation of the contaminants of concern.

impermeable not easily penetrated; the property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water

Composting

Composting has been used as a bioremediation process for many different organic compounds. It is widely employed to recycle nutrients in garden and yard waste. A finished compost can be used as a soil conditioner. Extending composting technology to new bioremediation applications requires experiments. The biodegradation process must be effective within the context of existing environmental conditions, and odors and gases that are generated by the process have to be strictly controlled.

In Situ Bioremediation

In situ processes (degrading the contaminants in place) are often recommended because less material has to be moved. These processes can be designed with or without plants. Plants have been used because they take up large quantities of water. This helps to control contaminated water, such as a groundwater contaminant **plume**, in the soil. Aerobic (oxygen-using) processes may occur in the unsaturated layer of soil, the vadose zone, which is found above the water table. The vadose zone is defined as the layer of soil having continuously connected passages filled with air, while the saturated zone is the deeper part where the pores are filled with water. Oxygen moves in the unsaturated zone by diffusion through pores in the soil. Some plants also provide pathways to move oxygen into the soil. This can be very important to increase the aerobic degradation of organic compounds.

in situ in its original place; unmoved or unexcavated; remaining at the site or in the subsurface

plume a visible or measurable discharge of a contaminant from a given point of origin; can be visible, invisible, or thermal in water, or visible in the air as, for example, a plume of smoke

Fate of Various Organic Contaminants

Petroleum-contaminated soil has been remediated in situ with plants added to enhance the degradation processes. The biodegradation of phenol, oil, gasoline, jet fuel, and other petroleum hydrocarbons occurs in soil. When plants are present, soil erosion is reduced and more microbes are present in the plant root zone. Methyl tertiary butyl ether (MTBE), used in gasoline to enhance the octane rating of the fuel, is difficult to remediate because it is very soluble in water and is hard to break down using microbes normally present in soil. In vegetation-based bioremediation, MTBE is moved from the soil to the atmosphere along with the water that plants take up from soil and release to the air. The MTBE breaks down rapidly in the atmosphere. Benzotriazoles, used as corrosion inhibitors in antifreeze and aircraft deicer fluids, are treated by plant-based bioremediation. The benzotriazole adsorbs or sticks to the plant roots and ends up as part of the plant biomass. Trichloroethylene (TCE) is a common chlorinated solvent that is biotransformed in the soil. It can be taken up by plants along with water. Then the TCE diffuses into the atmosphere where it is destroyed by atmospheric processes.

Bioventing

Bioremediation requires good nutrient and environmental conditions for biodegradation. When oxygen is needed for oxidation of the organic contaminants, bioventing (pumping air into the soil) is often used. Sometimes, fertilizers are added to the soil. In certain places irrigation is necessary so that plants or microbes can grow. SEE ALSO ABATEMENT; BIODEGRADATION; BROWNFIELD; CLEANUP.

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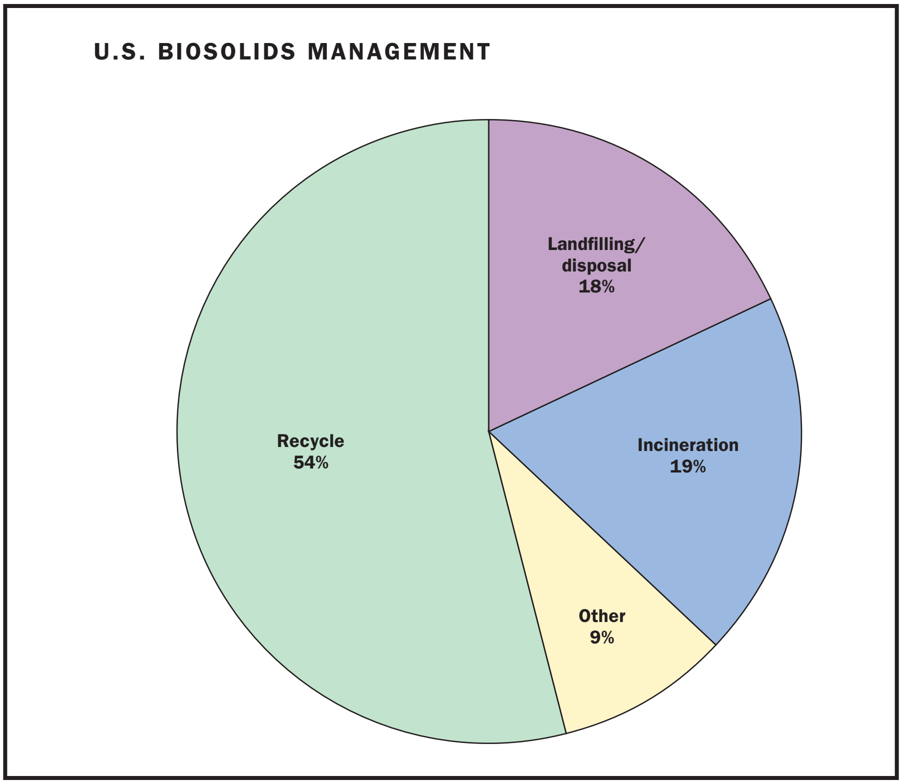
Larry Eugene Erickson and Lawrence C. Davis

Biosolids

Biosolids are nutrient-rich organic materials that result from the treatment of wastewater. They are commonly recycled as a fertilizer for crops and as a soil amendment to improve depleted soils. However, because biosolids have low levels of pollutants and pathogenic organisms, their use in the U.S. is regulated by the Environmental Protection Agency (EPA). Managing biosolids safely and effectively is an important issue for communities because of the quantities that are produced. The EPA estimates that the annual U.S. production of biosolids, recorded at seven million tons in 2000, will continue to increase.

In developed countries, biosolids are produced at treatment facilities that receive wastewater from homes, businesses, and industries. Domestic wastewater carries organic matter from food preparation, cleaning of clothes and cookware, and human waste. Industrial wastewater may contain organic material, oils, metals, and chemical compounds, but it is usually pretreated at the industrial facility to reduce the concentration of pollutants. Raw materials pumped from rural septic systems are often transported to treatment plants.

At the wastewater treatment facility, the solids from these various sources are first concentrated by settling out (primary treatment). Then they are biologically degraded (secondary treatment) by bacteria and other microorganisms feeding on the organic matter. To encourage the growth of the bacteria, the wastewater is aerated. As the microbes consume the dissolved and suspended organic matter, it is incorporated into their cells. Most disease-causing organisms (pathogens) are destroyed during this process. After further digestion or another equivalent treatment, the living and dead microbes form a stable residual material, biosolids.



In developing countries, lack of wastewater treatment is a serious problem. Raw sewage and other untreated organic wastes should not be confused with biosolids, whose treatment and use are regulated by environmental laws.

Using or Disposing of Biosolids

Biosolids must be recycled or disposed of somewhere in the environment. The 1993 Federal Sewage Sludge (biosolids) Standards define and regulate the three legal ways to manage biosolids: They can be incinerated, buried in a landfill, or recycled on land.

- Incineration—This is the method of disposal preferred by some eastern U.S. cities. Energy produced from burning biosolids can be captured and converted to electricity. Incinerators require technology to prevent the release of particulates and pollutants to the atmosphere. The biosolids are reduced to a small amount of ash, which is usually landfilled. About 22 percent of the biosolids in the United States are incinerated.
- Landfill Disposal—Biosolids can be mixed or layered with municipal solid waste and buried. Landfilling of biosolids usually occurs where agricultural lands for recycling are not readily available or the quality of the biosolids does not meet the strict EPA standard for recycling. Approximately 15 percent of the nation's biosolids are landfilled.
- Ocean Disposal—Prior to 1990, ocean disposal was the preferred method of disposing of biosolids in the world's coastal cites. The United States outlawed the ocean disposal of biosolids with the Ocean Dumping Ban Act of 1988. Europe and Australia then enacted similar bans.

NUTRIENT AND POLLUTANT CONTENT OF TYPICAL BIOSOLIDS COMPARED TO U.S. FEDERAL STANDARDS FOR BENEFICIAL USE

Element	Biosolids[1] (mg/kg dry)	U.S. Regulations[2] (mg/kg dry)
Nutrients		
Ammonia Nitrogen	14,500	
Organic Nitrogen	60,500	
Total Phosphorus	32,400	
Total Potassium	3,100	
Total Sulfur	10,700	
Magnesium	5,510	
pH	8.78	
Pollutants		
Arsenic	7.07	41
Barium	3.08	
Boron	15.1	
Cadmium	3.71	39
Chromium	46	
Copper	529	1,500
Iron	16,500	
Lead	141	300
Manganese	667	
Mercury	2.71	17
Molybdenum	11.1	
Nickel	35	420
Selenium	5.98	36
Silver	42	
Zinc	800	2,800

[1]Biosolids from King County (Seattle, WA) South Plant, 2000 data, annual means. mg/kg dry = parts per million.
[2]1993 Federal Sewage Sludge Standards 40 Code of Federal Regulations (CFR) Part 503. Pollutant concentration limits for exceptional quality biosolids.

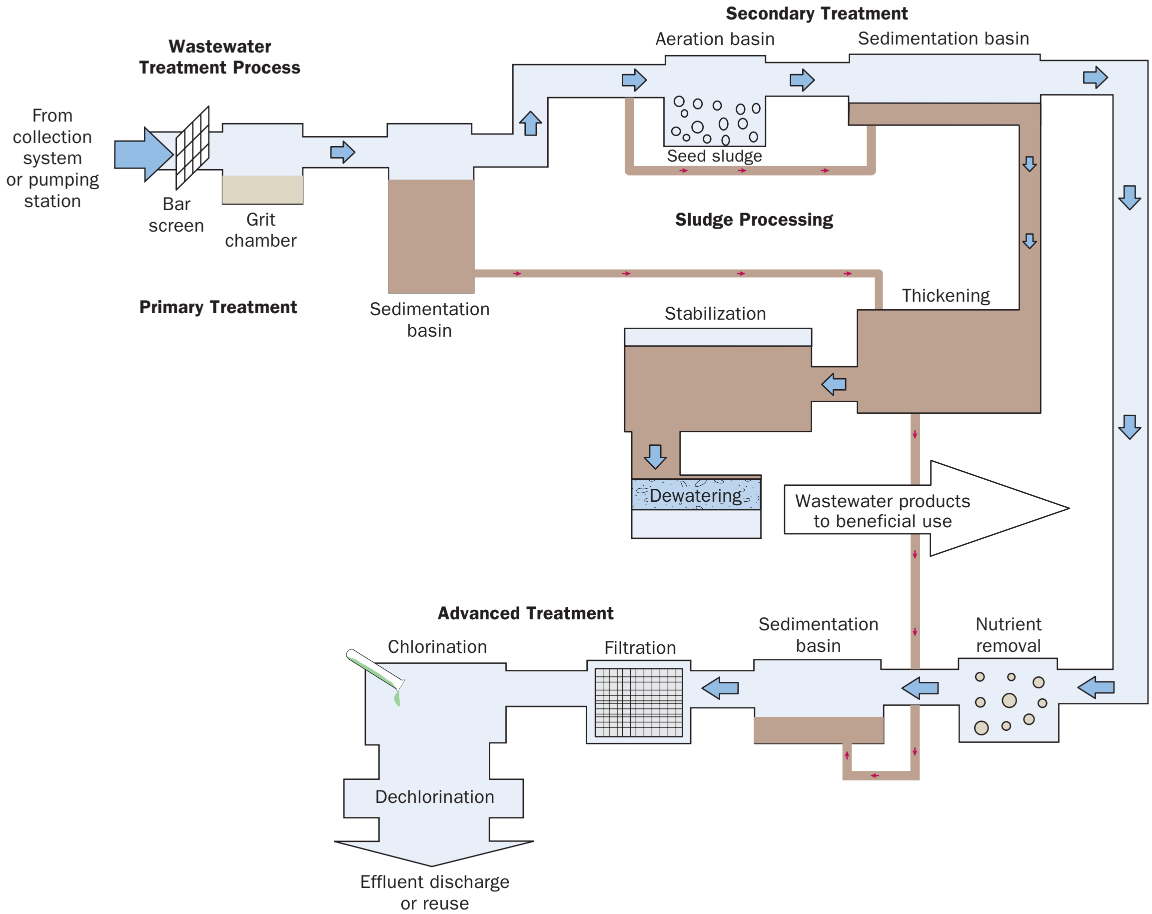
- Beneficial Use—Biosolids can be used to fertilize agricultural crops and forests, reclaim mines and disturbed lands, cover landfills, and make compost for soil amendment and landscaping. Most of the biosolids in this country, about 63 percent, are put to beneficial use. The EPA predicts that this will increase to 70 percent by 2010.

Biosolids are desirable soil amendments because they add nutrients and organic matter. All the elements essential for plant growth are found in biosolids, including the macronutrients (nutrients needed in large amounts) nitrogen, calcium, phosphorus, and sulfur and micronutrients such as boron, manganese, zinc, and copper. Organic matter benefits the soil in many ways. It improves water infiltration and helps hold water and nutrients for use by plants, thereby reducing runoff and erosion.

Evaluating Risks and Benefits

U.S. biosolids quality standards are based on risk assessments conducted by scientists at the EPA and the Department of Agriculture. After evaluating the pollutants in biosolids, scientists selected nine elements that had the greatest potential to harm humans, livestock, wildlife, or the environment. They used risk assessments to calculate the permissible increases in soil and crop pollutant levels from repeated applications of biosolids. The regulatory standards (see table) were then set below the level that would cause harm.

However, not all scientists agree with the U.S. risk assessments and standards. They caution against allowing soil pollutant concentrations to rise above background levels. Several European countries use this precautionary philosophy as the basis for their regulations. Periodically, the EPA



BIOSOLIDS REMEDIATE METAL-CONTAMINATED SOILS

The mining and processing of metal ores have contaminated soils in many countries. In the vicinity of lead (Pb) and zinc (Zn) mines and smelters, soils may have Pb and Zn concentrations as high as 20,000 mg/kg. These soils—with their high metals, low pH, and lack of nutrients and organic matter—are toxic to plants. Land around the mines is acidic and barren, often with blowing dust and metals leaching into ground and surface waters.

Three such sites on EPA's Superfund list—Palmerton, Pennsylvania; Leadville, Colorado; and Bunker Hill, Idaho—have demonstrated that biosolids mixtures can restore soils and vegetation. Biosolids combined with a calcium carbonate material such as lime or wood ash create a fertile soil and vigorous, self-sustaining plant growth. Iron and phosphates in biosolids adsorb lead and convert it to an insoluble compound, chloropyromorphite. Wood ash raises soil pH and prevents Zn from being taken up by plants or leached. Biosolids supply nutrients and organic matter for rebuilding soil and soil microbial communities.

Similar results have been reported in Upper Silesia, Poland, where lands have been contaminated by toxic coal and smelter wastes. New secondary treatment plants in the region will be producing a supply of biosolids for future restoration projects.

A douglas fir tree with (left cuts) and without (right cuts) biosolids application. There is a more than 100 percent increase in tree growth with biosolids. Each "tree ring" represents one year of growth. (King County photo by Ned Ahrens. AP/Wide World Photos. Reproduced by permission.)

has asked the U.S. National Academy of Sciences (NAS) to review the federal regulations for biosolids. The NAS review in 1995 concluded that "the use of biosolids in the production of crops for human consumption when practiced in accordance with existing federal guidelines and regulations, presents negligible risk to the consumer, to crop production and to the environment." The NAS reviewed the regulations again in 2002 and concluded, "There is no documented scientific evidence that the federal regulations have failed to protect public health."

Most researchers agree that the effects of organic compounds, metals, and microorganisms in biosolids are not harmful to humans or the environment if managed carefully. Many studies have shown that metals in biosolids are chemically bound in stable compounds and will not easily move into ground and surface waters.

Still, some land application projects are controversial, especially if they release odors. Odors at an application site can cause neighbors to raise questions about the safety and adequacy of regulations for biosolids recycling.

In response to the need for accurate and consistent information, the National Biosolids Partnership was established in 1997 by the federal EPA, Water Environmental Federation, and the Association of Metropolitan Sewerage Agencies. One of their goals is to encourage safe biosolids management practices in local communities through the use of environmental management systems. SEE ALSO Beneficial Use; Clean Water Act; Ocean Dumping Ban Act; Risk; Solid Waste; Wastewater Treatment; Water Pollution.

Internet Resource

National Biosolids Partnership Web site. Available from http://www.biosolids.org.

Peter S. Machno and Peggy Leonard

Bioterrorism *See Terrorism*

Bottle Deposit Laws

Bottle deposit laws, policy that requires the containers for carbonated beverages such as soft drinks and beer to carry a refundable deposit, have been a subject of controversy for more than thirty years. Designed to reduce waste by motivating more people to recycle bottles and cans, the strategy imposes a mandatory fee of usually five or ten cents per container that consumers pay at the cash register; when customers return the containers to stores selling the product or redemption centers, they get their deposit back. Since the concept was introduced in 1971 by Thomas Lawson McCall, then governor of the state of Oregon, the beverage industry has fought such legislation. Environmentalists and the recycling industry, however, have hailed the strategy as a major success.

Organizations such as the Grocery Manufacturers of America (GMA) argue that the system is outdated, unnecessary, and inefficient. The program was introduced, they say, during a time when recycling was just beginning to catch on, whereas today, curbside recycling programs, which focus on broad categories of materials such as plastics, or glass, instead of product-specific containers such as milk jugs or soda bottles, are flourishing. Additionally, they

argue, deposit laws require a vast, costly infrastructure to track collections and payments; sort containers by material, brand, and distributor; and transport collections between stores and processing centers. For such little gain, such critics say, the benefits of the laws hardly seem worth it when compared to their costs.

But according to one report released by Business and Environmentalists Allied for Recycling (BEAR), an alliance of businesses, recyclers, and environmentalists that studies recycling recovery rates, deposit programs achieve the highest levels of recycling. The eleven states that currently have bottle deposit laws (see table) recycle more waste than all other U.S. states combined, with each state reducing overall litter by 30 to 47 percent. Let the facts, recycling proponents argue, speak for themselves.

Some states are calling for an expansion of bottle deposit policy to include the containers for noncarbonated beverages such as juice, bottled water, and milk; Iowa, Maine, and Vermont currently include wine and liquor bottles in their state laws. In 2001 Maine even proposed a deposit on cigarettes, the leading litter item on Earth. SEE ALSO RECYCLING; SOLID WASTE.

STATES WITH BOTTLE DEPOSIT LAWS

State	Deposit in Cents (varies by size/ refill or nonrefill)
California	2.5–5
Connecticut	5
Delaware	5
Hawaii	5
Iowa	5
Maine	5–15
Massachusetts	5
Michigan	10
New York	5
Oregon	2–5
Vermont	5–15

SOURCE: Container Recycling Institute. "Bottle Bill Resource Guide." Available from http://www.bottlebill.org.

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Dave Brian Butvill

Brower, David

DEAN OF THE MODERN ENVIRONMENTAL MOVEMENT (1912–2000)

Often called Earth's best friend, David Ross Brower built a fire under the environmental community and kept it stoked for more than half a century. Sound-bite genius, both gracious and fierce, Brower was a master organizer, and his story is the story of the modern environmental movement.

David Brower. (©Roger Ressmeyer/Corbis. Reproduced by permission.)

During seven decades of environmental activism, Brower helped transform the Sierra Club from a small, genteel group of hikers to a powerhouse political force and helped found more than thirty environmental groups, such as the mainstream League of Conservation Voters and Friends of the Earth.

Brower led successful campaigns to prevent dams in Dinosaur National Monument and the Grand Canyon, aided Howard Zahniser in establishing the National Wilderness Preservation System, and helped add nine areas to the National Wilderness Preservation System, from the Point Reyes National Seashore in California to New York's Fire Island. He was nominated for the Nobel Peace Prize three times.

Brower was also one of the first environmental leaders to adamantly oppose nuclear power. His stance against the Diablo Canyon nuclear power plant in California led to his forced resignation as the executive director of the Sierra Club after seventeen years.

As Brower grew older and the planet became more polluted, he was transformed into the most creative and radical green activist of his generation. He launched the Earth Island Institute, which organized the consumer-led boycott that resulted in dolphin-safe tuna. As a coalition builder, Brower brought union workers and environmentalists together to found the Alliance for Sustainable Jobs and the Environment.

Brower later served several terms on the Sierra Club's board of directors, before finally retiring when he was in his eighties. "The planet is burning," he said. "And all I hear from them is the music of violins." SEE ALSO Environmental Movement.

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Dan Hamburg

Brownfield

A brownfield is a property which was once was home to a viable commercial or industrial operation but, because there is no longer an adequate market demand for that operation, the property sits idle, partially because of possible environmental contamination, waiting for a new function.

It is estimated that there are 500,000 to one million brownfields nationwide, but this number is difficult to confirm and there is reason to believe that the number is higher. Contamination will vary with the nature and size of the commercial or industrial operation that once occupied the site. A large steel plant may have covered more than 200 acres and may have contaminated the soil and groundwater with heavy metals, the concentration of which will be greatest near to the source of contamination and will lessen as the distance from the source increases. A dry cleaning operation or a gas station may cover less acreage and may leave behind contamination in the form of solvents, as may be the case for the former operation, and gasoline and petroleum products for the latter.

In the United States, the federal-level brownfield initiative evolved in the mid-1990s with the removal of less severely contaminated sites from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priority List (NPL), thus opening them up for redevelopment. The federal program has encouraged the development of state-level voluntary action (or voluntary cleanup) programs, with provisions including site-specific, risk-based cleanup standards, limitation of buyer and lender liability, and pilot funding for environmental investigations and remedial actions associated with soil, **surface water**, and **groundwater** contamination. Risk-based cleanup standards assure that the level of remediation is consistent with the proposed future use of the property.

surface water all water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, seas, estuaries, etc.)

groundwater the supply of freshwater found beneath the Earth's surface includes; aquifers, which supply wells and springs

Provisions for buyer and lender liability are important to protect the future owners from the excessive costs and other potential ramifications of

environmental contamination that they did not cause. Pilot funding is provided by the federal and state governments as seed money to initiate and promote investigation and evaluation activities on otherwise inactive sites. The hope is that incentives will help to gather information that will remove some of the fears about site development and quicken the return of the property to productive use within the community.

In practice, brownfield development is very complex. Successful strategies for brownfield development are often site specific because site conditions and location, as well as the local and regional economic conditions, will dictate "what will work" and "what will not work" on a brownfield. Generally speaking, the most successful sites will be a mixed-use development inclusive of residential, retail, office/commercial and recreational space. In addition to concerns about environmental contamination, there are many factors that complicate brownfield development, the most important of which are (1) local and regional land use planning and real estate demands, (2) regional political climate, and (3) financing and the options for sharing financial risk

Liability with respect to brownfield generally occurs in three forms and all result in unexpected costs. The first occurs when the remediation efforts uncover more contamination than was originally estimated. This can result in considerable cost overruns in the site development phase of the project. The second form of liability arises when a nearby landowner or neighbor claims that they have been harmed by environmental contamination migrating from the property. The third form of liability occurs when future development on the property uncovers previously undetected environmental contamination. In Europe, postindustrial site development has the same complexity, but the approach and the role of the government is very different. It is difficult to generalize about Europe as a whole, but for instance, in the Czech Republic, there is a National Property Fund to which application can be made to obtain the monies required to remediate an old factory (such as a steel plant) that was previously owned and operated by the government.

Most of the discussion of brownfield development centers on urban brownfields: inner city properties, sometimes postindustrial sites, that have been idled because of changing economic conditions. Intelligent development of brownfields takes advantage of the existing infrastructure (transportation, water supply, wastewater removal, electricity lines, and gas conveyance lines), and minimizes the potential for future brownfields. A brownfield is created when there is no longer a need for the current use of the property and the property has suspected environmental contamination. If, in the redevelopment of the brownfield, one can preclude the occurrence of environmental contamination and design the building and infrastructure to have flexible use, then in the event of a change in the market demand, the property may more readily adapted for an alternate use, thereby preventing the site from becoming idled once again. Brownfield development also reduces the demand for greenfields, or undeveloped properties on the outskirts of the city, by reusing previously developed land.

In this way, urban brownfield development, sometimes referred to as infill development, can help control urban sprawl. The "Waterfront" development, in an urban neighborhood bordering the city of Pittsburgh, is a 200-plus-acre steel plant that has been converted into a mixed-use site including light industrial, entertainment, retail, and residential space. Within

the Pittsburgh city limits, the largest remaining piece of undeveloped property was a slag pile. Currently under construction, Summerset at Frick Park will have more than seven hundred housing units when fully completed. SEE ALSO ABATEMENT; BIOREMEDIATION; COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA); CLEANUP; INDUSTRY; LAWS AND REGULATIONS, UNITED STATES; SUPERFUND.

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Deborah Lange

Gro Brundtland. (©Reuters NewMedia Inc./Corbis. Reproduced by permission.)

Brundtland, Gro

NORWEGIAN PRIME MINISTER AND ENVIRONMENTALIST (1939–)

In her life, Gro Harlem Brundtland has served society in three distinct capacities—as a medical doctor, a politician, and an environmentalist. She initially worked as a physician and then moved into the political arena as an environmental minister in the Norwegian government. Her success in this capacity led to her election as Norway's first female prime minister and influence on international treaties and conferences.

After attending medical school, Brundtland took a job with the city of Oslo as assistant medical director at the Board of Health. The opportunity to further evolve professionally came in 1974 when she joined the Norwegian cabinet as the ruling Labor Party's new environmental minister. As environmental issues grew to play a larger role in the Norwegian political arena, Brundtland's power base expanded. Her concern for the environment made her increasingly popular with many Norwegians.

That popularity led to Brundtland's election as the prime minister of Norway in 1981. She became the country's first female prime minister and, at age 42, the youngest person to ever hold that office. Although her first term as the leader of Norway was frustrating and lasted only one year, Brundtland remained the leader of the country's Labor Party, and in 1986 she was reelected prime minister.

In between, her leadership skills landed her an opportunity to conduct one of the most intensive studies on the future of the global environment ever undertaken. Called the World Commission on Environment and Development, this United Nations commission in the 1980s focused on solving the problems of poverty without destroying or severely depleting the world's natural resources.

Ultimately, the commission created a report, titled *Our Common Future*. Because of Brundtland's leadership in preparing it, the document also became known as *The Brundtland Report*. "The time has come for a marriage of economy and ecology so that governments and their people can take responsibility not just for environmental damage, but for the policies that cause the damage," the commission stated in its report. Brundtland's leadership on this United Nations effort helped cement her role as a leading voice in the evolving global concern for the environment.

In 1998 Brundtland took office as the Director General of the World Health Organization, a position she still held in 2002. SEE ALSO EARTH SUMMIT; MONTRÉAL PROTOCOL; TREATIES AND CONFERENCES.

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Kevin Graham

Burn Barrels

People used to think that burning household trash and yard waste in an open barrel was an inexpensive, good way to get rid of it. However, today's packaging and products are often made from plastics, dyes, and other synthetics. When burned, these cause air pollution and, in a number of U.S. states and municipalities, it is illegal. Burn barrels operate at relatively low temperatures, typically at 400 to 500° Fahrenheit (F) and have poor combustion efficiency (municipal incinerators run in the 1200 to 2000° F range).

As a result, many pollutants are generated and emitted directly into the air. Backyard trash and leaf burning often release high levels of toxic compounds, some of which are **carcinogenic**. Smoke from burning garbage often contains acid gases, heavy metal vapors, carbon monoxide and other sorts of dangerous toxins. One of the most harmful pollutants released during open trash burning is dioxin, a known carcinogen associated with birth defects. Dioxin can be inhaled directly or deposited on soil, water, and crops, where it becomes part of the food chain. Research has demonstrated that a single burn barrel can generate as much dioxin as a municipal incinerator serving thousands of households. SEE ALSO AIR POLLUTION; CANCER; CARBON DIOXIDE; COMPOSTING; DIOXIN; HEAVY METALS; HOUSEHOLD POLLUTANTS; INCINERATION; RECYCLING; REUSE; SOLID WASTE; WASTE REDUCTION.

carcinogenic causing or aggravating cancer

Internet Resource

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Susan L. Senecah

CAFOs *See Agriculture*

C

Cancer

Cancer develops when cells in the body begin to grow out of control. Normal cells grow, divide, and die. But cancer cells, instead of dying, continue to

LIFETIME RISK OF CANCER FROM KNOWN CAUSES

Risk Factor	Risk
Excessive sun exposure	1 in 3
Cigarette smoking (one pack or more per day)	8 in 100
Natural radon in indoor air at home	1 in 100
Outside radiation	1 in 1,000
Environmental tobacco smoke (in room with a smoker)	7 in 10,000
Human-made chemicals in indoor air at home	2 in 10,000
Outdoor air in industrialized areas	1 in 10,000
Human-made chemicals in drinking water	1 in 100,000
Human-made chemicals in most foods (including pesticides)	1 in 100,000 or less
Chemical exposure at uncontrolled hazardous waste sites	1 in 10,000 to 1 in 1,000

SOURCE: U.S. Environmental Protection Agency

grow and form new abnormal cells. Cancer cells often travel to other body parts where they grow and replace normal tissue. This process, called metastasis, occurs as the cancer cells are transported by the bloodstream or lymph vessels. Cancer cells develop because of damage to DNA. DNA carries the genetic information of every cell and directs all its activities. When DNA becomes damaged, the body is able to repair it. But in cancer cells, the damage is not repaired.

Some anomalies that increase the risk of cancer are present at birth in the genes of all cells in the body, including reproductive cells. These can be passed from parent to child. This is known as inherited susceptibility and is an uncommon cause of cancer. Most cancers result from genetic changes that occur over decades within the cells of a particular organ. These changes can usually be traced to an interaction of genetics and the environment, including behavior and lifestyle. Other factors that influence cancer risk are age, race, gender, preexisting disease, and nutritional impairment.

Environmental Factors

The term "environment" includes air, water, and soil, as well as substances and conditions in the home and workplace. It also includes:

- Diet
- Use of tobacco, alcohol, or drugs
- Exposure to chemicals
- Exposure to ultraviolet (UV) light from the sun and in tanning parlors and other forms of radiation

Only recently have scientists proved the existence of an interaction between environmental toxins and one's genetic makeup. Researchers hope that when people are knowledgeable about inherited susceptibility, they will be motivated to avoid carcinogens that increase their risk. For example, scientists at the State University of New York at Buffalo report evidence that a genetic variation (mutation) in a gene which helps detoxify carcinogens may put smokers with this mutation at increased risk for breast cancer.

Overexposure to UV radiation from the sun and cigarette smoking pose the greatest known risks of developing cancer. Other factors contribute much less significantly to cancer development. The approximate lifetime risk of developing cancer from known causes is listed in descending order of risk in the bar graph. Note that the risk from exposure to chemicals at hazardous waste sites can vary widely, depending on the chemical, and the length and type of exposure. For comparison, consider the fact that the lifetime risk of death from a fall is 1 in 270, according to the National Safety Council. The lifetime risk of any given American dying as an automobile passenger or a motorcycle rider are 1 in 244 and 1 in 1,536 respectively.

Categories of Carcinogenicity

Substances or agents that cause cancer are called **carcinogens**. The more likely something is to cause cancer, the more **carcinogenic** it is. Cigarette smoke is more carcinogenic than chlorinated community drinking water.

carcinogen any substance that can cause or aggravate cancer

carcinogenic causing or aggravating cancer

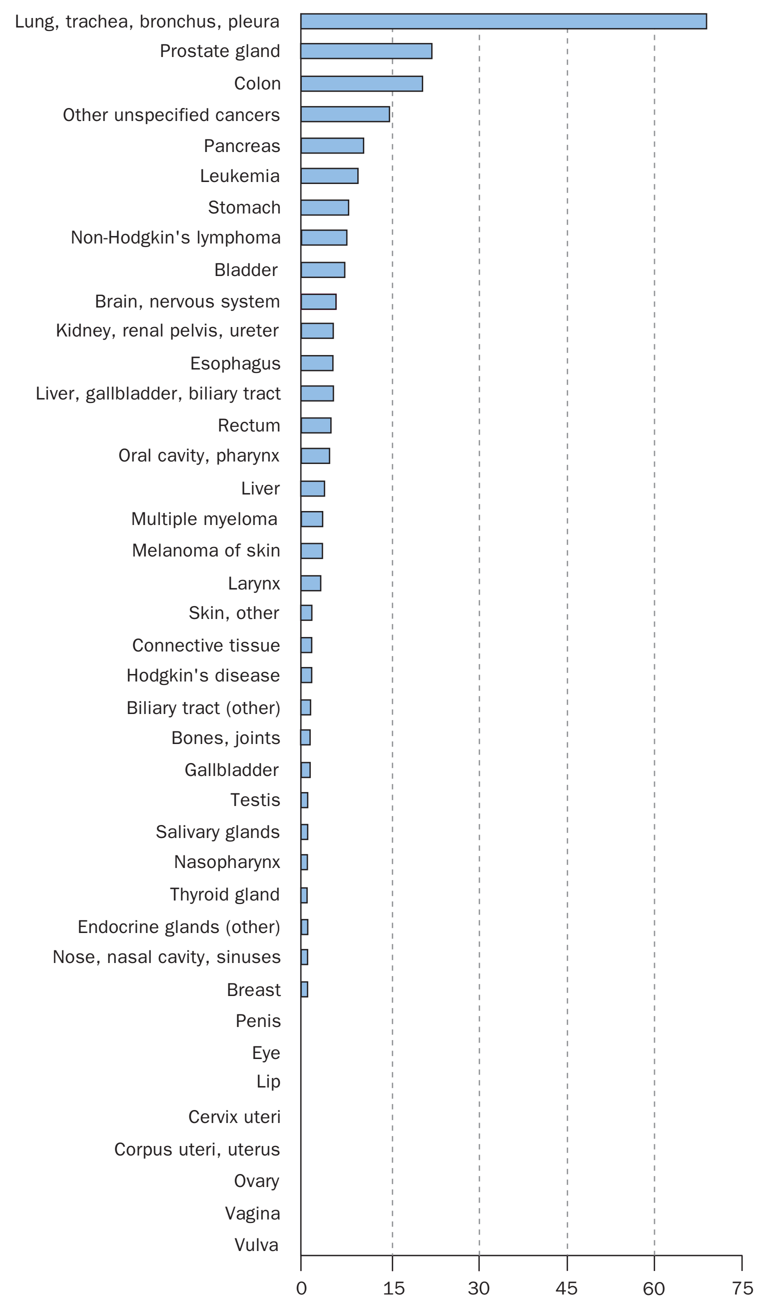
The U.S. Environmental Protection Agency (EPA) classifies carcinogenicity into five categories. A category A substance is known to cause cancer in humans, generally based on epidemiological (large population) data showing sufficient evidence to support a causal association between exposure to the substance and cancer. Category A carcinogens include asbestos, benzene, radon, and coal gasification. Category B includes "probable" human carcinogens known to cause cancer in animals but not yet definitively shown to cause cancer in humans. Category B carcinogens include chloroform, carbon tetrachloride, gasoline, and progestins. Category C includes "possible" human carcinogens for which the data show "limited evidence" of carcinogenicity in the absence of human data. Chemicals for which the data are incomplete, inadequate, or ambiguous are "not classifiable" and reside in category D. Those in category E are "probably not carcinogenic."

Determining carcinogenicity can be a harrowing and lengthy process. For example, the debate over possible risks posed by electromagnetic fields (EMF) has been raging for decades. Magnetic fields originate from everything with an electrical current. Elevated field levels can occur in homes close to power lines, or occasionally from improper household wiring. A form of EMF called "extremely low frequency (ELF) electric and magnetic fields" recently was classified as "possibly carcinogenic" by the International Agency for Research on Cancer (IARC).

Concerns about EMF from power lines began to mount in the 1970s, when epidemiological studies first showed a possible link to childhood cancer. But the research has produced inconsistent and conflicting findings, leading the World Health Organization (WHO) in 2002 to launch a more complete series of follow-up studies.

Military personnel in proximity to radio frequency (RF) emitted by radar equipment may have an increased risk of brain cancer, according to a small published Israeli study. But when it comes to RF, cellular phones have been receiving the bulk of attention from the media and in lawsuits claiming that cell phone use resulted in plaintiffs' brain tumors. While researchers have shown that the use of these handheld devices increases a driver's risk of experiencing a traffic accident, the brain tumor connection remains unproved.

CANCER MORTALITY RATES PER 100,000 PERSONS AGE-ADJUSTED 1970 U.S. POPULATION WHITE MALES, ALL AGES, 1970 TO 1994



SOURCE: Cancer Mortality Maps & Graphs Web site, a service of the National Cancer Institute http://cancer.gov/atlasplus.

When a person develops a malignancy, it can be very difficult to attribute a particular cause or source. Though smoking underlies the bulk of environment-induced lung disease, there are other contributors or possible contributors in human surroundings. Some evidence suggests that air pollutants produced by the burning of fossil fuels play a role in causing lung cancer

among city dwellers. A high level of radon in the home—such as exists in parts of the Midwest and northeast—is a cancer risk factor, especially for smokers. Radon is a heavy, radioactive gaseous element formed by the natural decay or disintegration of radium in the earth's crust. Other environmental pollutants that may play roles in cancer include airborne arsenic and microscopic asbestos fibers inhaled into the lungs.

Radon is not alone in adding to the lethality of cigarette smoking. Asbestos exposure and smoking also multiply each other's lethality (a "synergistic" effect). On an individual basis, both smoking and asbestos exposure can cause lung cancer, but taken together, they multiply the risk of lung cancer significantly. Studies in the science of epidemiology confirm that the combination of smoking and asbestos exposure creates a risk of cancer much higher than just adding together their separate risks. Evidence suggests that asbestos-exposed workers who quit smoking can reduce their risk of developing lung cancer by as much as 50 percent within five years of quitting.

Comparison of a smoker's lung (r) to a normal lung (l). (Photograph by A. Glauberman. National Audubon Society Collection/Photo Researchers, Inc. Reproduced by permission.)

Cancer Clusters

The study of disease clusters is one method scientists use to study the public health implications of carcinogens. A cancer cluster is defined as a greater-than-expected number of cancer cases that occurs within a group of people in a geographic area over a specific period of time. Studies of suspected cancer clusters usually focus on heredity and environment. Such clusters may be suspected when people report that several family members, friends, neighbors, or coworkers have been diagnosed with the same or related cancer(s).

In the early 1980s a leukemia cluster was identified in the Massachusetts town of Woburn. In a case that was the subject of *A Civil Action*, later made into a major motion picture, three companies were accused of contaminating drinking water and causing illnesses. The case went to trial in *Anne Anderson*, *et al.* v. *W.R. Grace & Co.*, *et al.* Six families alleged that chemicals dumped by the defendants caused leukemia in members of those families. Two closed municipal water wells—which were the focus of the families' case—were found to be contaminated with EPA-listed hazardous substances, including trichloroethylene (TCE). Although the U.S. Department of Health and Human Services (HHS) lists TCE as "reasonably anticipated to be a human carcinogen," IARC has determined that trichloroethylene cannot currently be classified as such.

In any case, this action became a poster trial for the difficulty of linking certain events to a cluster of individual illnesses. The incredibly complex case involved thirty-three plaintiffs, two defendants, a mountain of conflicting geological and medical testimony, and multiple claims including negligence, nuisance, and emotional distress. A direct and incontrovertible connection between the pollution caused by W.R. Grace and the cancer cluster was never confirmed.

The prospect of a larger cancer cluster was investigated in New York State. *The Breast Cancer and the Environment on Long Island Study* was carried out in response to anecdotal reports that environmental toxins elevated breast cancer rates among women in the region. Chief among the suspects were polycyclic aromatic hydrocarbons (PAH), which are caused by incomplete combustion of various chemicals including diesel fuel and cigarette smoke, and organochlorine compounds, which are found in many pesticides. In

August 2002 scientists reported that organochlorine compounds were not associated with the elevated rates of breast cancer on Long Island. However, the same investigators did suggest it was possible that risk in some individuals may be associated with organochlorine exposures because of individual differences in metabolism and the ability of one's body to repair DNA damage.

The researchers also found that PAHs were associated with a modest 50 percent increased risk for breast cancer in susceptible women exposed to high levels of the compounds. But for the population of women as a whole, no specific environmental factor could be tied to the incidence of breast cancer. Some have complained that the study failed to take into account the possible effects of leaks from a nearby nuclear reactor, and there have been public accusations that the study avoided the so-called "nuke connection" for political and financial reasons.

The thousands of individuals who were in and around the World Trade Center in lower Manhattan on and immediately after September 11, 2001, may constitute a cluster of future disease. Public safety personnel, rescue workers, and local residents were exposed to a lingering pall of dust and debris following the collapse of the twin towers and other buildings. Superheated and aerosolized building materials created an incalculable number of toxic compounds. The full effects on the health of those exposed may not be known for decades.

In conclusion, the interplay between our environment and cancer is complex and not yet fully understood. It is increasingly clear that the unborn and very young children are particularly susceptible to environmental toxins such as endocrine-disrupting herbicides and insecticides. Adult cancer risk can be greatly reduced by avoiding tobacco products and limiting sun exposure. Known carcinogens often encountered in workplaces and homes include pesticides, asbestos, arsenic, uranium, and certain petroleum products. SEE ALSO ASBESTOS; HEALTH, HUMAN; PCBS (POLYCHLORINATED BIPHENYLS); RADON; RISK.

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Bruce K. Dixon

Cancer Alley, Louisiana

In 1987 some residents in the tiny community of St. Gabriel, Louisiana, called Jacobs Drive, the street on which they lived, "cancer alley" because there were fifteen cancer victims in a two-block stretch. Half a mile away, there were seven cancer victims living on one block. The eighty-five-mile stretch of the Mississippi River from Baton Rouge to New Orleans was formerly referred to as the "petrochemical corridor" but after reports of numerous cases of cancer occurring in the small rural communities on both sides of the river, the entire area became known as cancer alley.

In 2002 Louisiana had the second-highest death rate from cancer in the United States. Although the national average is 206 deaths per 100,000, Louisiana's rate is 237.3 deaths per 100,000.

In 2000 Toxic Release Inventory (TRI) data showed that Louisiana ranked second throughout the nation for total onsite releases, third for total releases within the state, and fourth for total on- and offsite releases. Louisiana, which has a population of 4,469,970 people, produced 9,416,598,055 pounds of waste in 2000. Seven of the ten plants in the state with the largest combined on- and offsite releases are located in cancer alley, and four of the ten plants with the largest onsite releases in the state are located there.

Industrial accidents and accidental releases are common occurrences in cancer alley. For instance, in 1994 Condea Vista (Conoco) located in Lake Charles reported thirty-nine chemical accidents that released 129,500 pounds of chemicals. The following year, Condea Vista reported ninety accidental chemical releases. In 1997 the company was charged with contaminating local groundwater supplies by discharging between 19 to 47 million pounds of ethylene dichloride (EDC), a suspected human carcinogen, into a local stream. In 1999 hundreds of unskilled laborers filed suit against Condea Vista, claiming they were exposed to EDC while cleaning up a spill from a leaking underground pipeline.

The population of cancer alley is primarily African-American and low-income. Despite the large number of industrial facilities—more than 136—unemployment is high in many communities and most residents do not have a college education. Nevertheless, the inhabitants of cancer alley have been organizing to limit the siting of noxious facilities in their neighborhoods. The most famous case of community resistance occurred in Convent, where, in 1996, Shintech announced plans to build a $700 million chlor-alkali vinyl complex that would be permitted to emit 611,700 pounds of contaminants into the air. The battle between Shintech and Covent garnered international attention. Finally, in 1998 Shintech decided to abandon its plans to build a plant in Convent.

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Dorceta E. Taylor

Carbon Dioxide

Carbon dioxide (CO_2) is a nontoxic, odorless, and colorless gas present in trace concentrations in the atmosphere. The molecule is linear with a central carbon atom doubly bonded to two oxygen atoms (O=C=O). Natural sources of CO_2 include volcanic outgassing, animal respiration, **biomass** decay, and oceanic evaporation. Removal processes include photosynthesis and **dissolution into the oceans**.

biomass all of the living material in a given area; often refers to vegetation

dissolution into the oceans dispersion in ocean water

CO_2 is a long-lived gas, with an atmospheric lifetime of more than one hundred years. It is a natural greenhouse gas and plays an important role in regulating Earth's climate. Like water vapor, CO_2 traps outgoing infrared radiation emitted by Earth into space. By absorbing this energy, the atmosphere warms the earth, a process known as the natural greenhouse effect. Without carbon dioxide and water in the atmosphere, the earth's average surface temperature would be below 0°F, turning oceans into ice and dramatically altering life as it is known.

CO_2 is also an **anthropogenic** greenhouse gas, ranked number one for its contributions to global warming. At the beginning of the Industrial Era (around 1750), CO_2 concentrations worldwide were approximately 280 parts per million (ppm); by 1999 concentrations reached 367 ppm. (One ppm equals one molecule of CO_2 for every million molecules of air, or 0.0001 percent.) CO_2 emissions continue to rise; the average rate of increase since 1980 is 0.4 percent per year.

anthropogenic human-made; related to or produced by the influence of humans on nature

The recent rise in anthropogenic CO_2 is attributed largely to fossil fuel combustion (73 percent) and land use conversion resulting from deforestation (25 percent). When oil, coal, or natural gas is burned to generate energy, the by-products are CO_2 and water. Due to heavy fossil fuel consumption, the United States leads the world in anthropogenic CO_2 emissions (see table). In 1996 the United States contributed more than 50 percent of the 1.027×10^{16} grams of total global CO_2 emissions.

As concentrations of CO_2 increase in the atmosphere, more outgoing infrared energy is trapped (energy that would have escaped to space), warming the earth's atmosphere and surface. The Intergovernmental Panel on Climate Change estimates that the global surface temperature has increased by 1.1°F since the late nineteenth century, due to increases in CO_2 and other greenhouse gases.

International efforts are underway to reduce CO_2 and other greenhouse gases. As of December 2001, 186 countries ratified the Kyoto Protocol, an international agreement to reduce CO_2 and other greenhouse gas emissions. CO_2 emissions can be reduced by reforestation and **afforestation** efforts by changing cropland management practices such as tilling, and by reducing the combustion of fossil fuels. The United States did not sign the protocol, but promotes voluntary development of climate-friendly technologies (i.e., renewable energy sources) coupled with changes in land use and forestry practices. Examples of the latter include decreased deforestation, increased reforestation, and agricultural practices designed to increase soil carbon. SEE ALSO Electric Power; Emissions Trading; Global Warming; Greenhouse Gases; Petroleum; Vehicular Pollution.

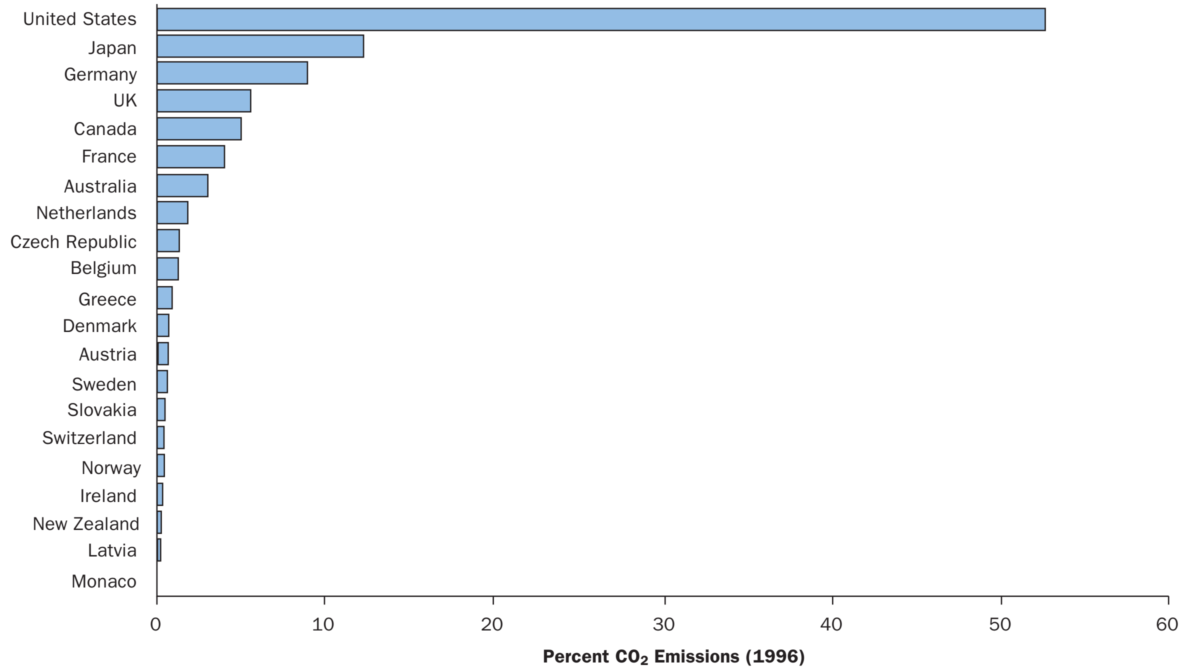
afforestation conversion of open land to forest

O=C=O

Carbon Dioxide

Chemical structure of carbon dioxide (CO_2).

ANTHROPOGENIC EMISSIONS OF CO_2 (EXCLUDING LAND USE CHANGE AND FORESTRY), IN THE UNITED STATES AND OTHER COUNTRIES, 1996



SOURCE: United Nations Framework Convention of Climate Change, Conference of the Parties, FCC/COP.1998/INF.9.

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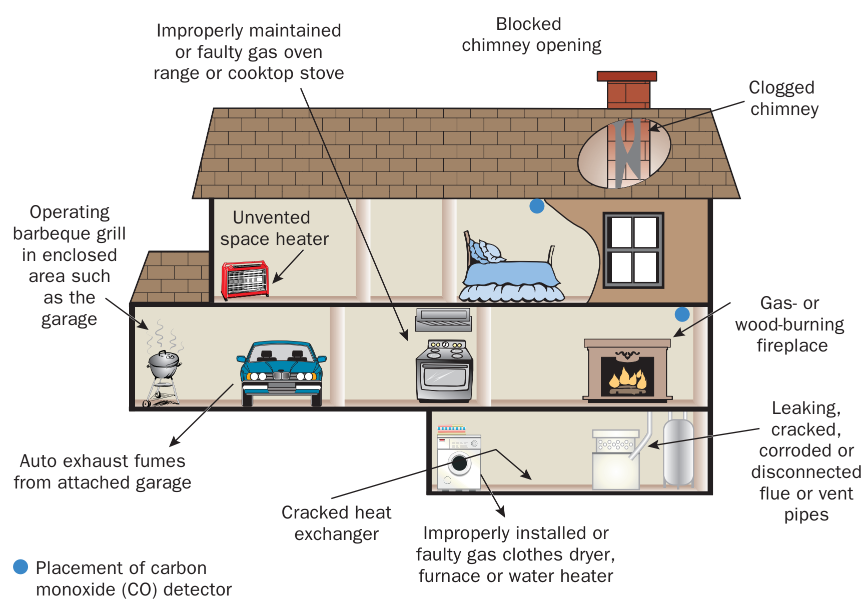
Marin Sands Robinson

Carbon Monoxide

Carbon monoxide is an invisible, odorless, and poisonous gas with the chemical formula CO. Because of its toxicity, the U.S. Environmental Protection Agency (EPA) regulates CO. The gas is a by-product of incomplete combustion (burning with insufficient oxygen). Its major source is vehicle exhaust (60 percent). Other sources include water heaters and furnaces, gas-powered

SOURCES OF CARBON MONOXIDE IN THE HOME



engines (boats and lawn mowers), charcoal and wood fires, agricultural burning, and tobacco smoke.

CO is classified as an indirect greenhouse gas. It does not contribute to global warming directly, but leads to the formation of ozone. Ozone is the major air pollutant formed in photochemical smog and a potent greenhouse gas.

Human exposure to elevated CO impairs oxygen uptake in the bloodstream. Under CO-free conditions, oxygen is transported from the lungs to tissues by hemoglobin. When CO is present, it mimics the shape of oxygen and binds instead to the hemoglobin. The molecule is not easily released, blocking further oxygen uptake, and ultimately depriving organs and tissues of life-sustaining oxygen. The symptoms of CO poisoning range from dizziness, mild headaches, and nausea at lower levels to severe headaches, seizures, and death at higher levels.

The EPA national outdoor air quality standard for CO is nine parts per million or ppm (0.0009 percent) averaged over an eight-hour period. The gas is life-threatening after three hours at 400 ppm (0.04 percent) and within minutes at 1.28 percent. In 1996, 525 deaths in the United States were attributed to unintentional and 1,988 deaths to intentional CO poisoning.

Exposure to CO can be reduced by assuring adequate ventilation when near any combustion source. Indoor cooking with charcoal and running gas-powered engines inside a garage are both dangerous and should be avoided. Fuel-burning appliances and fireplaces ought to be routinely inspected.

CO detectors are available to detect less obvious sources, such as a malfunctioning furnace. The sensors operate in one of three ways: They mimic the body's response to CO (biomimetic detectors), they allow a heated metal oxide to react with the gas (metal oxide detectors), or they facilitate a reaction

using platinum electrodes immersed in an electrolyte solution (electrochemical detectors). The lowest level that a CO alarm can detect is 70 ppm. SEE ALSO AIR POLLUTION; GLOBAL WARMING; GREENHOUSE GASES; INDOOR AIR POLLUTION; OZONE; VEHICULAR POLLUTION.

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Marin Sands Robinson

Careers in Environmental Protection

Careers in environmental protection involve jobs that help reduce the negative environmental impacts of today's actions, restore damaged ecosystems to health, or build sustainable ways of life for the future. Fifty years ago, most of today's environmental careers did not exist. Today, the field of environmental jobs is one of the fastest-growing job markets; there are more than one hundred environmental-protection careers to consider—ranging from environmental law, politics, journalism, and education, to highly technical and scientific jobs in such fields as environmental engineering, biology, chemistry, and architecture.

What happened to create so many new jobs in environmental protection? The environmental movement happened. During the past half century, American society began to adopt a new set of environmental values. The public also started to explore the idea that people could often save money—and sometimes even make money—by protecting the environment.

As a result of the environmental movement, environmental advocates and legislators worked together to create a large infrastructure of environmental laws and regulations to protect the environment and human health. New regulations called for policymakers, lobbyists, citizen monitors, attorneys, managers, and conservationists to make and enforce new policies. Scientists, engineers, and other specialists were enlisted to study problems and develop and implement solutions to problems such as oil spills, air pollution, landfills, and contaminated ground water.

As new technological advances were developed to combat ongoing crises, new environmental occupations emerged. By the beginning of the twenty-first century, over $400 billion was spent annually worldwide on environmental protection, supporting hundreds of thousands of interesting jobs.

Opportunities for Almost Every Interest

Today, many people can find careers in environmental protection that match their personal skills and dreams. For example, someone interested in working outdoors might choose to become a conservation biologist, park ranger, wildlife manager, or forester. A person who enjoys working with the public might explore working as an outreach specialist in environmental education,

Workers testing and analyzing ground water. (©David Sailors/Corbis. Reproduced by permission.)

public relations, environmental journalism, or nature interpretation—or in some other communications specialty.

Some of today's hottest careers are in environmental sciences, environmental law, environmental business, conservation, environmental engineering, environmental communications, environmental lobbying, and the social sciences. Yet, like any job, the demand for experts in any field of environmental protection can rise or fall.

Environmental Career Opportunities

Environmental protection occupations fall into five categories:

1. Environmental research
2. Environmental outreach: education, communications, and advocacy
3. Natural resource management
4. Environmental engineering and sciences
5. Environmental policy and legislation and regulation171

Environmental Research and Teaching

Environmental research is conducted by scientists and science technicians who study all aspects of the environment.

Jobs include:

Ecologists

Biologists

Zoologists

Biochemists

Aquatic biologists

Marine biologists

Botany

Microbiologists

Physiologists

Air specialists

Sample Jobs

- Zoologists study all animals. Their research focuses on life processes, diseases, behavior, and other features of the animal world.
- Microbiologists study the growth and characteristics of microscopic organisms such as bacteria, algae, and fungi.
- Ecologists study the interactions between organisms and their environment.

Environmental Outreach: Education, Communications, Advocacy, and Fundraising

Environmental communications specialists are responsible for communicating knowledge about the environment to the public, the government, and private businesses. Environmental outreach specialists can be found teaching in schools, helping firms understand environmental goals, interpreting nature at state parks, writing for publications, and lobbying legislators.

Jobs include:

Environmental educators

Environmental journalists

Communications specialists

Interpretive naturalists

Environmental advocates

Technical writers

Organizers

Lobbyists

Fund-raisers

Sample Occupations

- Environmental educators teach the public about the environment. Environmental educators are hired to work in schools, nature centers, and in industry.

A microbiologist examines a core sample from a bio-remediation demonstration. (U.S. EPA. Reproduced by permission.)

- Environmental journalists report on environmental issues. They are hired to work for magazines, newspapers, journals, television, and radio. Some work for environmental advocacy groups or organizations.
- Fund-raisers (also called developers) raise money for specific environmental causes. Fund-raisers are employed by private and government organizations.

Natural Resources Conservation and Management

Conservation and natural resource managers maintain and manage natural resources. Some specialists are required to balance multiuse recreation with the preservation of natural resources.

Jobs include:

Wildlife conservationists

Foresters

Fishery and wildlife managers

Fish and game wardens

Energy and conservation technicians

Forestry and conservation technicians

Sample Occupations. Foresters manage and protect forests so that both people and the environment benefit. Foresters oversee a multiuse system, including municipal watersheds, wildlife habitats, and outdoor recreation areas. They deal with fire protection, landscape design, municipal waste recycling, and the care of trees.

Environmental Engineering and Sciences

Environmental engineers specialize in either preventing or cleaning up pollution or environmental emergencies. Engineers who work to prevent pollution look for and help defend against potential sources of damage to the environment.

Engineers who specialize in cleaning up accidents decide how to clean up environmental problems quickly and efficiently. Engineers are called upon to resolve complex problems such as oil spills, hazardous waste, and polluted lakes and wetlands.

Jobs include:

Geographic information systems analysts

Chemical engineers

Civil engineers

Water and air quality engineers

Solid and hazardous waste engineers

Marine biologists

Pollution control technicians

Wastewater treatment plant operators

Sample Occupations

- Geographic information systems (GIS) specialists use computers to demonstrate interactions between human activities and ecological systems. GIS analysts are in demand at planning agencies, research centers, and consulting agencies, because these specialists can produce important data that is needed to make decisions.
- Air-quality managers do highly sophisticated monitoring, conduct chemical and statistical analyses, and perform computer modeling to determine whether industries are complying with air-quality regulations. They also conduct research to create new technologies to reduce air pollution.
- Hazardous-waste managers include environmental engineers, groundwater scientists, toxicologists, industrial hygienists, and other specialists who manage hazardous wastes. One of their prime goals is to reduce the generation of hazardous wastes.
- Solid-waste managers are environmental engineers, urban planners, business and finance managers, and other professionals who develop systems to manage solid waste safely.

A worker analyzes data at a computer workstation. (U.S. EPA. Reproduced by permission.)

- Water-quality managers include chemical, civil, environmental, and mechanical engineers, hydrologists, toxicologists, planners, and other professionals who reduce pollutants in lakes, streams, rivers, and wetlands.

Environmental Policy, Legislation, and Regulation

Professionals working in environmental policy, legislation, and regulation are responsible for developing and enforcing environmental regulations.

Jobs include:

Environmental lawyers

Paralegals

Environmental Protection Agency (EPA) inspectors

Environmental Compliance Agency workers

Sample Occupations

- Environmental attorneys and lawyers are experts in environmental law who help companies understand the complex environmental rules and regulations that businesses need to follow. Some environmental lawyers help the government create environmental policies and regulations.
- Environmental inspectors help the government inspect companies to make sure that they are complying with federal or local environmental regulations.

Environmental Planning and Analysis

Environmental planners and analysts are involved in finding ways to reduce damage to the environment.

Jobs include: Environmental planners and environmental analysts.

Sample Occupations

- Environmental planners develop plans for specific communities to protect environmental quality.
- Environmental analysts research, identify, and analyze different sources of pollution to determine their effects on the environment and find alternative ways to handle projects in an environmentally sensitive manner.

Building a Career

Most careers in environmental protection require some training or college-level education—and often graduate-level or professional training. Anyone interested in pursuing a career in this field needs to consider educational and training requirements carefully.

Choosing the courses or a major for a career in environmental protection is not usually as clear-cut as it is for a career in law or medicine. However, many universities now have degree programs in environmental studies that allow students to explore many options. Also, many employers offer internships in environmental protection jobs; these internships offer students a chance to learn about specific jobs.

Who Hires Environmental Specialists?

Jobs in environmental protection can be found in both government and private organizations—many of which are not specifically environmentally oriented—as well as in industry.

Here is a brief list of places to look for jobs in environmental protection. Most agencies have their own Web site with current job listings.

In the public sector:

- Federal government agencies, such as the Bureau of Land Management, the U.S. Fish and Wildlife Service, the Environmental Protection Agency, and the U.S. Forestry Department
- Local government, such as state and community agencies including the state Departments of Natural Resources
- Universities

A professor's challenge to do something about "those hippie students hanging out in Harvard Yard, making noise about the environment but doing nothing about it" led to the creation of a nonprofit organization that by 2002 had placed more than 7,500 college students in environmental internships. The Environmental Intern Program, founded in 1972 with a $3,000 gift, placed eleven interns in its first year. By 2001, now called the Environmental Careers Organization, the budget was some $15 million and ECO placed more than 750 interns at 124 sites in thirty states and three U.S. territories. For info and to apply, go to http://www.eco.org.

In the private sector:

- The environmental industry (businesses that produce products and services designed to protect the environment)
- Regulated companies
- Law firms
- Financial and insurance industries
- Environmental consulting firms
- Nonprofit organizations (there are hundreds to choose from, including the Nature Conservancy, Sierra Club, and the National Audubon Society)
- Lobbyist organizations.

The Future for Environmental Careers

The field of environmental protection is still new, so it is difficult to predict which environmental careers will have the greatest prospects in the future. New environmental regulations, new technologies, and new environmental crises may influence which jobs are in greatest demand. Universities are attempting to help students prepare for jobs in environmental protection by offering degrees in many areas of environmental studies.

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Corliss Karasov

Cars

See Vehicular Pollution

Carson, Rachel

SCIENTIST, ECOLOGIST, WRITER OF *SILENT SPRING* (1907–1964)

In 1963 an important national symbol almost became extinct. According to the U.S. Fish and Wildlife Service, only 417 pairs of bald eagles nested in the continental United States that year. Eagle eggs cracked open easily because the parents ate prey containing the chemical dichlorodiphenyl trichloroethane (DDT), a pesticide widely used to kill insects that fed on field crops. In 1972, the use of DDT was banned in the United States, and the outcome was remarkable. By 1995, the bald eagle totaled 4,712 pairs and was no longer on the endangered species list. Credit for the eagle's comeback is often given to the effects of one book: *Silent Spring* (1962), by Rachel Louise Carson. This quiet, determined woman not only helped save the eagle, but also raised the public's awareness of the damaging effects of pesticide pollution upon all living things. After her death, Carson was generally recognized as the founder of twentieth-century environmentalism.

Rachel Carson. (Corbis-Bettmann. Reproduced by permission.)

Carson had a master's degree in zoology from Johns Hopkins University, but excelled in writing about science for the public. She was planning what would have been the nation's first popular book on ecology when she heard that hundreds of songbirds were dying in a Maryland wildlife sanctuary sprayed with DDT. The birds were much like the canary that miners used to carry into a coal shaft: When it inhaled poisonous gases, it would stop singing, warning the miners to escape. Similarly, Carson reasoned that without careful use, pesticides could be harmful or deadly to humans as well as insects and birds. She dropped her plans to write about ecology and instead did research on pesticides. When she wrote about her new project in the *New Yorker* magazine in June 1962, the public and critical reaction was explosive.

Many reviewers from the news media criticized her article, calling Carson an unreasonable, emotional, fear-provoking, and hysterical woman. Velsicol, a company that sold pesticides, pressured publisher Houghton Mifflin to drop the book by associating Carson with communists. Linda Lear writes in *Rachel Carson: Witness for Nature* (1997) that Velsicol sent a letter to the publisher suggested that she had some political involvement with the Soviet Union and identifying her with "sinister influences." Velsicol claimed that Carson intended to reduce U.S. food sources to equal the low food production of the eastern European countries allied with the Soviet Union. Velsicol

never retracted their claims. But the controversy between chemical company scientists and Carson's supporters greatly increased sales when the book was officially published on September 27, 1962. By the end of the year, *Silent Spring* was number one on the *New York Times* best-seller list.

Carson and her book have been linked to countless environmental milestones. Soon after the book's publication, President John F. Kennedy ordered the President's Science Advisory Committee (PSAC) to investigate pesticides, leading to federal regulation in 1964. DDT and other pesticides were later banned in the United States, although the chemical is still used in a few countries. Testifying before Congress, Carson suggested that a commission be created to coordinate pesticide policy—the first recorded version of what became the Environmental Protection Agency (EPA). Officials from President Jimmy Carter to Vice President Al Gore have recognized her leadership of the environmental movement. Finally, her book *Silent Spring* has become known as the first and most important statement about ecology to influence public policy in the twentieth century.

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Christine Oravec

Carver, George Washington

FARMER, AGRICULTURAL/FOOD SCIENTIST, EDUCATOR (1805–1943)

The **conservationist** agricultural practices developed by George Washington Carver at the beginning of the twentieth century increased agricultural sustainability for poor African-American farmers in the U.S. Deep South. An expert in revitalizing soil, Carver worked through the Tuskegee Institute in Alabama to publicize composting techniques and the importance of **crop rotation**, which helped combat soil depletion and pest infestation in the region's overcultivated cotton and tobacco fields.

conservationist a person who works to conserve natural resources

crop rotation alternation of crop species on a field to maintain soil health

Carver was born into slavery in Diamond Grove, Missouri, sometime between 1860 and 1864. His parents were lost to Confederate slave raiders. Formal education of blacks was not widespread, and only through his own tenacity did Carver become Iowa State's first African-American college graduate, earning a bachelor of science degree in 1894 and a master of science degree in 1896.

In 1896, Carver took a job at the Tuskegee Institute, where he discovered how rotating alternative crops such as sweet potatoes, black-eyed peas, and especially peanuts restored nitrogen to depleted soil. Carver also experimented with **hybridization** to increase plant resistance to common pests. To popularize his methods, Carver wrote instructional manuals, and in 1906 he founded the "moveable school" to give hands-on demonstrations to illiterate farmers. This school on wheels taught approximately 2,000 farmers per

hybridization formation of a new individual from parents of different species or varieties

George Washington Carver. (©Corbis. Reproduced by permission.)

month during its first summer, and served as a model for the U.S. Department of Agriculture's extension program.

One of his forty-four instructional manuals, *How to Grow the Peanut and 105 Ways of Preparing It for Human Consumption*, published in 1916, revealed new uses for peanuts and their byproducts, including paper, paints, insecticides, shaving cream, peanut butter, and bar candy. An American peanut industry developed as a result, and Carver became its chief spokesman. In 1921 he addressed Congress to urge high import duties on peanuts grown in Asia. After this successful presentation, Carver's fame spread and he became the first African-American scientist to achieve national acclaim.

Carver died at Tuskegee on January 5, 1943, but continues to receive posthumous awards. His childhood home is a national monument, and in 1990, he was inducted into the Inventors Hall of Fame. SEE ALSO Agriculture.

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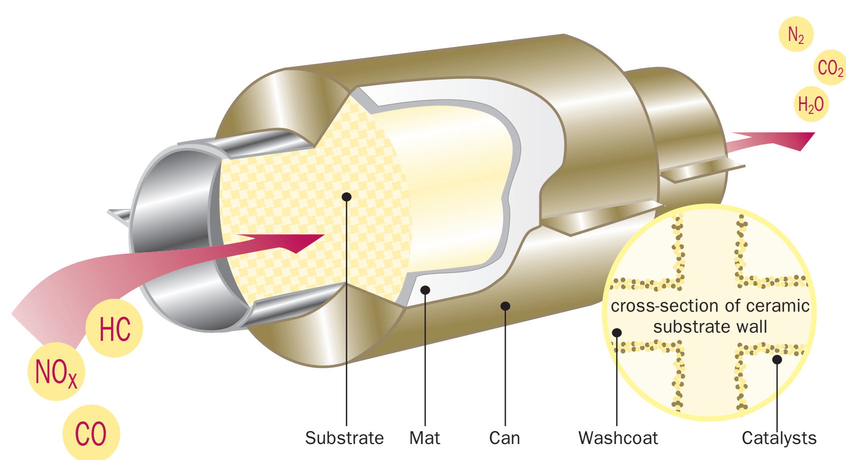
Anne Becher and Joseph Richey

Catalytic Converter

The catalytic converter in an automobile is an expanded section of exhaust pipe occurring upstream of the muffler in which pollutants generated in the engine are converted to normal atmospheric gases. It is an essential element in the emissions control system of modern automobiles. This technology was introduced in the United States in the late 1970s and became legally required by the early 1980s because of more stringent exhaust emission control standards. Early catalyst systems, as applied to vehicles with carburetors, attempted to oxidize carbon monoxide (CO) and unburned hydrocarbons (HC) to carbon dioxide (CO_2) and water vapor, using air added by means of an air pump or rapidly actuating valve system. Although constructed from a high-surface-area alumina substrate with a noble metal (usually platinum) on the surface, their effectiveness was limited by extreme conditions of service. These problems include high temperatures (greater than 1,000°C) exacerbated by a large and variable "engine-out" pollutant load and constant vibration from roadway and engine sources.

The replacement of carburetors with computer-controlled, port fuel injection and precise air/fuel ratio control based on exhaust oxygen sensing has allowed catalytic converters to operate with close to 100 percent efficiency and better longevity, often exceeding 100,000 miles. The addition of a ceria wash coat in the form of a thin layer of porous cerium oxide and

COMPONENTS OF A CATALYTIC CONVERTER



SOURCE: Adapted from Corning.

rhodium metal in conjunction with the platinum now allow for both good longevity and "three-way" operation. Not only are the small amounts of residual CO and HC oxidized, but the nitric oxide pollution emissions are simultaneously reduced to nitrogen (and some nitrous oxide, a potent atmospheric greenhouse gas, but otherwise nonpoisonous). The tetraethyl lead present in gasoline as an octane booster in the 1970s was removed not because of its effects on human health, but because it rapidly poisoned catalysts. Its removal, although coincidental, has had enormous benefits for human and environmental health. Current pressure to reduce the sulfur content of fuel arises, in part, from evidence that sulfur has a similar, but much smaller effect on catalyst longevity and effectiveness. SEE ALSO GREENHOUSE GASES; LEAD; OZONE; VEHICULAR POLLUTION.

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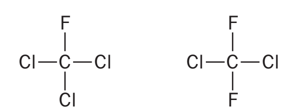
Donald Stedman

Cell Phones *See Electromagnetic Fields*

CERCLA *See Comprehensive Environmental Response, Compensation, and Liability Act*

CFCs (Chlorofluorocarbons)

Chlorofluorocarbons (CFCs), once described as "miracle chemicals," cause the breakdown of the ozone layer that protects the earth from the sun's ultraviolet (UV) radiation. CFCs have no significant natural sources. They were first manufactured in the 1930s, and industries soon found a wide variety of applications for them due to their chemical **unreactivity** and heat-absorbing properties. CFCs have been used as **refrigerants** in air conditioners and refrigerators, in aerosol spray cans, in manufacturing foams as industrial **solvents**, and as cleaning agents in the manufacture of electronics. One U.S. chemical industry gave them the trade name of "Freons," and the term has since become a household word.



CFCs

Chemical structure of CFCs.

unreactivity lack of chemical reactivity

refrigerant liquid or gas used as a coolant in refrigeration

solvent substance, usually liquid, that can dissolve other substances

Chemically, CFCs are a subset of the more general class of compounds known as halocarbons (carbon- and halogen-containing compounds). CFCs are halocarbons that contain only the elements carbon, chlorine, and fluorine. The most common CFCs are small molecules containing only one or two carbon atoms. For example, a common refrigerant has the chemical formula of CCl_2F_2, which in an industry-devised shorthand is noted as CFC-12.

inertness inability to react chemically

solubility the amount of mass of a compound that will dissolve in a unit volume of solution; aqueous solubility is the maximum concentration of a chemical that will dissolve in pure water at a reference temperature

breakdown degradation into component parts

Scientists initially believed that CFCs would be harmless in the earth's atmosphere because of their chemical **inertness**. This inertness, and their lack of **solubility** in water, give CFCs a long life span in the atmosphere (tens to hundreds of years, depending on the CFC). In the late 1970s, scientists began to realize that CFCs do break down in the upper atmospheric region known as the stratosphere, where the sun's UV waves are more intense. The UV-induced **breakdown** releases free, highly reactive chlorine and bromine atoms from the CFCs. Several subsequent chemical reactions are kick-started by this process, including the breakdown of the stratospheric ozone layer.

The ozone layer is important to humans and other life on earth because it absorbs harmful UV radiation (acting as a sort of UV "shield") Long-term effects on humans' excessive UV exposure include skin cancer, eye damage (cataracts), and suppression of the immune system.

CFCs are now recognized as harmful chemicals because of their ozone-depleting properties. As a consequence, an international agreement known as the Montréal Protocol was forged in 1987 and later strengthened by amendments to decrease and eventually end the use of these chemicals. CFCs are also potent greenhouse gases and are components of pending international agreements regarding greenhouse gases, the most notable being the Kyoto Protocol (1997). SEE ALSO Global Warming; Greenhouse Gases; Montréal Protocol; Ozone.

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Christine A. Ennis

Chávez, César E.

FOUNDER OF UNITED FARM WORKERS OF AMERICA (1927–1993)

César Estrada Chávez was born near Yuma, Arizona, on March 31, 1927. Eleven years later, his family lost their farm and joined several hundred thousand other migrants working California's crops under terrible conditions. By the time of his death at 63, Chávez had organized farmworkers, improved their wages and living conditions, shaped public awareness, and prompted government regulations that reduced their exposure to dangerous pesticides.

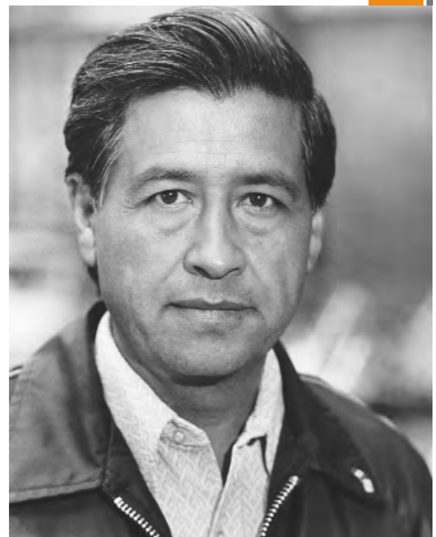
After dropping out of school and serving in the U.S. Navy during World War II (1944–1945), Chávez did farm work for seven years. Beginning in 1952, he registered voters and organized chapters of the Community Service Organization (CSO), a Mexican-American equal rights movement, in California. He left CSO in 1962 to establish a separate union that eventually became the United Farm Workers of America (UFW) in 1973.

After Chávez led a series of migrant worker strikes against vineyards, most grape growers signed contracts restricting dangerous pesticides as a result, long before comparable government restrictions were put in place. Chávez continued the struggle because most growers persisted in their abusive pesticide practices and refused to renew their contracts with proactive migrant workers.

When research found that 300,000 people in central California suffered from pesticide-related illnesses, and there was a high incidence of cancer among children in the same region, Chávez initiated another grape boycott

in 1984. He fasted for a life-threatening thirty-six days in mid-1988 to augment his antipesticide protest. Ultimately, his controversial nonviolent strategies significantly raised American awareness of farm pesticide dangers, changed public policies, and concentrated his union's efforts well into the 1990s.

In 1994 President Bill Clinton posthumously awarded Chávez the U.S. Medal of Freedom. Days later, Governor Pete Wilson signed a bill making Chávez's birth date an official holiday in California. In carrying out his life's mission, Chávez exemplified a unique blend of beliefs, behaviors, and commitments along with nonviolence, egalitarianism, political activism, volunteerism, solidarity/unity, and respect for all cultures, religions, and lifestyles. SEE ALSO Activism; Labor, Farm; Pesticides.



César E. Chávez. (©Hulton-Deustch Collection/Corbis. Reproduced by permission.)

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José B. Cuellar

Chemical Spills *See Abatement; Cleanup; Disasters: Chemical Accidents and Spills*

Chlorination *See Water Treatment*

Chloroflurocarbons *See CFCs*

Citizen Involvement *See Public Participation*

Citizen Science

If asked to picture a scientist, most people probably would imagine a professional peering into a microscope or poring over statistics on a computer screen. Science does not belong solely to such professionals, however. Ordinary citizens from all walks of life have a huge stake in science and technology as well, which can both enrich their lives with new discoveries and damage their world with pollution. Citizen science is a movement that recognizes the contribution which such concerned citizens can make to scientific policy and research, particularly when it comes to environmental issues.

Several high-profile court cases have proved the power of citizen science. For example, it was citizen volunteers in Woburn, Massachusetts, who gathered data about the unusually large number of area children stricken with

leukemia, a cancer of the blood-forming cells. The efforts of these volunteers led to a trial, where two large corporations were accused of polluting the town's water, which was thought to have played a role in the children's illness. The trial, in turn, inspired a best-selling book by Jonathan Harr and a popular movie starring John Travolta, both titled *A Civil Action*.

Another famous example of citizen science is less controversial, but just as powerful in its own way. In 1900 the National Audubon Society launched its Christmas Day Bird Count, in which amateur birdwatchers were asked to tally and report the number of birds they spotted on one day. The first year, twenty-seven people took part. Today, this event, the longest-running of all citizen science projects, attracts more than 50,000 participants. Several other large-scale bird counts have started as well. These projects help scientists spot local changes in bird populations, which may signal an environmental threat, such as groundwater pollution or poisoning from the improper use of pesticides.

Some citizen science programs enlist people of all ages to help with the hands-on collection of technical data. For example, Global Learning and Observations to Benefit the Environment (GLOBE) is a program that has involved more than one million elementary through high school students in the United States and one hundred other countries. The students learn to take accurate measurements of the air, water, soil, and vegetation in their area. They then share their data via the Internet. Scientists, in turn, use the measurements to improve their understanding of the global environment.

Although GLOBE is sponsored by the U.S. government, many citizen science programs grow out of grassroots organizations. For example, it is estimated that over 550,000 people in the United States are involved in monitoring rivers in their area. The River Watch Program is a national organization that provides training and support to local groups working to protect and restore their rivers. As these examples show, individuals do not need lab coats, fancy equipment, or a big research budget to make very real and important contributions to environmental science. SEE ALSO ACTIVISM; CANCER; EARTH DAY; ENVIRONMENTAL MOVEMENT.

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Linda Wasmer Andrews

Citizen Suits

Citizen suits are lawsuits that are brought by individuals or nonprofit groups under the provisions of certain environmental laws. Because agencies do not catch and prosecute all violators of environmental statutes, citizen suits can

be extremely useful, empowering anyone with an interest in environmental protection to demand that laws be enforced. Provisions for citizen suits have been created on both the federal level and in some states' environmental statutes. On the federal level, provisions for citizen suits are generally more narrow, limited to specific laws. Conversely, when states allow citizen suits, there are usually fewer hurdles for plaintiffs. State-level citizen suits also tend to have a greater impact on overall enforcement.

To bring any claim in the United States, plaintiffs must show that they have standing, meaning that they have been personally injured by the defendants' actions. Under most citizen suit provisions, individuals are automatically granted standing to bring claims against violators. Industry has made efforts to limit this practice, but in a 2000 appeal, citizen suit standing was upheld. In *Friends of the Earth* v. *Laidlaw Environmental Services*, the U.S. Supreme Court reinforced and extended its recognition of standing to include claims brought against violators even after they have come into compliance with the law.

Citizen suits have improved the enforcement of environmental laws over the past quarter century. In response, during the 1980s, polluters created a defense strategy against these lawsuits. Strategic Litigation against Public Participation (SLAPP) suits are civil lawsuits brought by alleged polluters against the citizens who attempt to compel enforcement action against them. These suits are usually based on claims of defamation, discrimination, or contract interference, and can effectively deter individuals from pursuing environmental enforcement cases. Some states have attempted to reign in SLAPP suits, but such actions continue to intimidate individuals. Despite certain industries' counteractive measures, however, citizen suits continue to be a valuable tool in environmental enforcement. SEE ALSO ACTIVISM; ENVIRONMENTAL CRIME; ENVIRONMENTAL IMPACT STATEMENT; LAWS AND REGULATIONS; NATIONAL ENVIRONMENTAL POLICY ACT (NEPA); NONGOVERNMENTAL ORGANIZATIONS (NGOs); POLITICS; PUBLIC PARTICIPATION; REGULATORY NEGOTIATION.

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Mary Elliott Rollé

Clean Air Act

The 1970 Clean Air Act (CAA), significantly amended in 1977 and again in 1990, regulates air pollution emissions from "stationary" sources (e.g., factories, smokestacks, etc.), mobile sources (e.g., motor vehicles), and certain "indirect" sources (e.g., highways, malls, parking lots, etc., that attract mobile

sources to the location). Specified "criteria" pollutants such as sulfur dioxide, nitrogen oxide, carbon monoxide, particulates (i.e., soot, fly ash, etc.), and lead are directly regulated, as are "hazardous" air pollutants that the EPA determines are likely to cause death or serious physical injuries. Congress listed some 189 hazardous air pollutants in its 1990 amendments to the original law. Many of these hazardous air pollutants are fairly common chemicals, such as benzene, dry-cleaning solvents, and others that pose scientifically verifiable health dangers. Although it has long been a criteria pollutant, lead is now known to be especially dangerous to human health. The 1990 amendments require further reductions in the criteria oxides that cause smog and acid rain.

Permitted sources have monitoring and reporting requirements. Permitting decisions are based, in part, on whether the location of a stationary source emitting a particular pollutant is in an "attainment area" for that pollutant (i.e., the local pollution generated by that pollutant does not exceed the specified threshold). Conversely, the area may be regarded as "nonattainment" in terms of that pollutant and the applicable standard (i.e., the threshold is exceeded), in which case allowable emissions will be severely curtailed. Mobile source emissions are regulated in the main by the EPA's establishment of specific emission standards for several classifications of vehicles; these are imposed on manufacturers. The 1990 amendments planned the development of "clean fuel" vehicles using hybrid or low polluting fuels and, especially for notoriously dirty urban buses, clean fuel fleets. Vehicle fuel is also regulated in regard to its constituents, with limitations imposed on gasoline sold in ozone or carbon monoxide nonattainment areas. After 1995, leaded gasoline was absolutely barred from commerce.

States exercise responsibility primarily by the formulation of State Implementation Plans (SIPs), which are subject to EPA approval. If a SIP is unavailable or ineffectively carried out by the state, the EPA enforces the act. Citizen suits are also permitted, whereby private citizens, subject to notice requirements, have the authority to act as private attorney generals in seeking judicial enforcement. They may not, however, recover damages. SEE ALSO AIR POLLUTION; DRY CLEANING; ELECTRIC POWER; LAWS AND REGULATIONS, UNITED STATES; TOXIC RELEASE INVENTORY; VEHICULAR POLLUTION.

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Kevin Anthony Reilly

Clean Water Act

The twentieth-century conflagration of Ohio's Cuyahoga River well illustrated the quandary of a nation whose water was so polluted that it burned. The modern Clean Water Act (CWA) is the result of a sequence of federal water pollution control statutes starting with the nineteenth-century enactment of the Rivers and Harbors Act (limited to navigation-impeding debris), the 1948 Federal Water Pollution Control Act (the first federal attempt to regulate water pollution), the 1965 Water Quality Improvement Act, and the 1972 Federal Water Pollution Control Act. This, as amended in 1977 and

again in 1987, was the template for the present statute. Although denoted the Federal Water Pollution Prevention and Control Act in the U.S. Code, the statute's common name is the Clean Water Act.

The CWA primarily governs the pollution of surface water, such as rivers, lakes, and streams. The CWA also regulates dredge and fill operations in wetlands, establishes criteria for ocean discharges, and regulates the oil pollution of water. In addition, it provides for state funding and includes research-oriented provisions.

The crux of the CWA lies in the requirements for a national permitting scheme for the pollution of surface waters. It provides for regulatory control of water pollution primarily by two mechanisms: enforcing "water-quality standards," typically established by states, and imposing technology based "effluent limitations" by means of permitting under the National Pollutant Discharge Elimination System (NPDES). Dischargers, such as publicly owned treatment works (POTWs), are required to utilize the best available pollution control technology in minimizing pollutants before they can obtain a permit to operate. The CWA contemplates the significant delegation of enforcement authority to qualifying states and state permitting under SPDES (i.e., "state" PDES) programs. The discharge of certain pollutants, such as toxic pollutants and medical wastes, is prohibited.

The EPA (except that the U.S. Army Corps of Engineers issues wetlands permits) or state agencies under qualifying state programs enforce the CWA. Citizen plaintiffs, subject to notice requirements specified in the statute, also may sue to enforce the act, although, similar to other federal environmental "citizen suit" provisions, not for the recovery of personal damages.

Enforcement of the CWA has received wide popular support. Despite the fact that it will not be possible to fairly evaluate its real value for quite some time, the CWA is generally considered an environmental success. SEE ALSO BIOSOLIDS; LAWS AND REGULATIONS, UNITED STATES; OCEAN DUMPING; OCEAN DUMPING BAN ACT; WASTEWATER TREATMENT; WATER POLLUTION.

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Kevin Anthony Reilly

Cleanup

The cleanup of environmental pollution involves a variety of techniques, ranging from simple biological processes to advanced engineering technologies. Cleanup activities may address a wide range of contaminants, from common industrial chemicals such as petroleum products and **solvents**, agricultural chemicals and metals, to **radionuclides**. Cleanup technologies may be specific to the contaminant (or contaminant class) and to the site. This entry addresses the cleanup of contaminated soil and water. Air pollution is addressed generally at the point of release by control technologies, because the opportunities to capture and recover airborne contaminants are limited once they are released into the atmosphere.

Cleanup costs can vary dramatically depending on the contaminants, the **media** affected, and the size of the contaminated area. Much of the

solvent substance, usually liquid, that can dissolve other substances

radionuclide radioactive particle, man-made or natural, with a distinct atomic weight number; can have a long life as soil or water pollutant

media specific environments—air, water, soil—which are the subject of regulatory concern and activities

Tractor-drawn tankers are being used to clear oil beached to the west of Angle Bay, following the grounding of the tanker *Sea Empress* off Milford Haven in southwest Wales, U.K., 1996. (©Bryan Pickering; Eye Ubiquitous/ Corbis. Reproduced by permission.)

remediation cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site or for the Asbestos Hazard Emergency Response program

remediation reduction of harmful effects; restoration of undisturbed site

Warsaw Pact nations allied with the former Soviet Union countries

remediation to date has been in response to such historical chemical management practices as dumping, poor storage, and uncontrolled release or spillage. Greater effort in recent years has been directed toward pollution prevention, which is more cost-effective than remediation. Programs such as Superfund in the United States, as well as parallel state programs, represent a commitment of billions of dollars to the cleanup of contaminated sites.

Many industry-specific cleanup programs (e.g., Florida's dry cleaner program) are funded by taxes or fees levied on that industry. Several Western European countries have environmental programs that are at least as aggressive as those in the United States. Countries with emerging economies are working hard to address environmental contamination with limited resources. Many cases of environmental contamination in former **Warsaw Pact**, for example, are associated with former Soviet military bases. In Poland, cleanup of several of these bases is under way. In Kluczewo, northwestern Poland, a former military base is reportedly the biggest and most contaminated such site in Central Europe. A skimming technique was used to remove liquid petroleum fuel from the subsurface followed by bioremediation of the remaining contaminated soil. The Polish government paid for the work with support from local sources.

Government involvement in environmental remediation includes consideration of the safety of the cleanup workers. Professionals involved in the cleanup of contaminated sites may have long-term exposure to a variety of hazardous materials and, as such, must be protected against adverse health

Two workers wearing gas masks and protective clothing loading debris contaminated by dioxin into tractor trailers. (©Bettmann/Corbis. Reproduced by permission.)

impacts. Such protection begins with the planning and implementation of characterization and clean up efforts. Minimizing contact with contaminated media is the optimal method for managing risk to site workers. When such contact is necessary, or when the nature of the contamination is unknown, as in initial characterization activities, personnel protective equipment (PPE) is used to protect site workers. The major routes of exposure for workers at contaminated sites are through dermal (skin) or inhalation pathways. PPE is categorized by the level of protection it provides to these two exposure pathways, ranging from simple dermal protection such as overalls and gloves to fully encapsulating suits with supplied air. The level of protection needed is based on the nature and extent of knowledge of site conditions—less information requires more protection.

In most cases, it is financially or physically impractical to completely remove all traces of contamination. In such cases, it is necessary to set an acceptable level of residual contamination. Evaluating experimental toxicity data and then extrapolating to potential exposure scenarios forms the basis for such decisions. The result of these evaluations is an estimate of risk for given adverse outcome (e.g., cancer or death). Risk-based target levels typically determine when cleanup is complete. As a result, evolution of cleanup technologies has yielded four general categories of remediation approaches: (1) **physical removal** (with or without treatment); (2) in situ **conversion** by physical or chemical means to less toxic or less mobile forms; (3) **containment**;

physical removal digging up and carting away

conversion chemical modification to another form

containment prevention of movement of material beyond the immediate area

natural attenuation reduction in a pollutant through combined action of natural factors

and (4) passive cleanup, or **natural attenuation**. Combinations of technologies may be used at some sites.

Physical Removal

The physical removal of contaminated soil and groundwater has been, and continues to be, a common cleanup practice. However, physical removal does not eliminate the contamination, but rather transfers it to another location. In ideal cases, the other location will be a facility that is specially designed to contain the contamination for a sufficient period of time. In this way, proper removal reduces risk by reducing or removing the potential for exposure to the contamination. Removal options vary dramatically for soil and groundwater, as described below.

Soils. Excavation of contaminated soils works well for limited areas of contamination that are close to the ground surface. Under ideal conditions, the disposal location is a designed, regulated, and controlled disposal facility (e.g., a landfill or incineration facility). Alternatively, contaminated soil may be excavated and consolidated in a prepared facility on-site. Prepared disposal facilities range from simple excavations with impermeable covers (caps) to sophisticated containment structures such as those used in modern landfills. Landfills typically consist of multiple layers of impermeable materials—often combinations of synthetic (plastic) liners and compacted layers of dense clays; piping to collect and transport liquids generated within the landfill (leachate); and systems of sensors within and surrounding the landfill to detect leaks. When contaminated soil is **excavated**, transported, and disposed of properly, physical removal can be an effective and economical cleanup option.

excavate dig out

Treatment of excavated soil, to either destroy the contaminant or to reduce its toxicity or mobility often is associated with physical removal. Treatment following removal will differ with the chemical of concern. Many organics (e.g., solvents, pesticides, oils) may be incinerated or landfilled effectively. Some metals require conversion to compounds that will not react with other substances before being transferred to a landfill. Treatment options also can be troublesome as landfill space decreases and public opposition to incineration increases in some areas. However, effective air pollution controls are available to manage incinerator emissions, and engineering for landfill construction now includes sophisticated liners, **leachate** controls, and management practices to prevent groundwater contamination or other forms of cross-pollution.

leachate water that collects contaminants as it trickles through wastes, pesticides, or fertilizers; leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, ground water, or soil

Beyond excavation, more selective removal technologies have been developed for contaminants in soil, including soil washing, which uses processing equipment and chemical solvents to "wash" contaminants from soil. In practice, soil washing often is complicated and expensive. Phytoextraction—the use of plants to remove soil contaminants—has achieved favor in some applications. Selected plant species may remove and concentrate inorganic contaminants such as **heavy metals** and **radionuclides** in the above- or below-ground tissues. If phytoextraction is successful, the resulting plant tissue will have high levels of the soil contaminant and be classified as hazardous waste, requiring appropriate treatment or disposal options (see previous section). To date, phytoextraction has been used only at relatively small sites.

heavy metals metallic elements with high atomic weights; (e.g. mercury, chromium, cadmium, arsenic, and lead); can damage living things at low concentrations and tend to accumulate in the food chain

radionuclide radioactive particle, man-made or natural, with a distinct atomic weight number; can have a long life as soil or water pollutant

One of the best-documented cases of heavy metal phytoremediation in the United States was conducted at a former battery manufacturing site in Trenton, New Jersey. The land surrounding this urban facility that was in operation from the 1930s until 1980 was highly contaminated with lead. For two vegetation seasons Indian mustard plants were used to reduce the concentration of lead in the soil to below regulatory limits. This cleanup effort illustrates the potential for innovative, biological remediation technologies.

Sediments are the inorganic (e.g., clay, silt, sand) and organic (plant and animal) materials that settle to the bottom of water bodies. Aquatic sediments often become contaminated by a wide variety of man-made chemicals including agricultural chemicals such as pesticides that are washed into water bodies, industrial chemicals that are released into water bodies or that leak from containment structures as well as the many products that are transported by water. Contamination in aquatic sediments may affect the organisms that live within the sediments, or may bioaccumulate through the food chain as larger species feed on organisms that have absorbed the contamination. Remediating such contamination requires choosing between the risks associated with leaving the contamination in place and the risks associated with excavating the sediments (and resuspending them in the water), transporting and disposing of them.

Groundwater. Liquid or solid chemicals, when disposed of by burial or direct release onto the ground surface, can migrate down into the soil structure and come in contact with groundwater. Final disposition of these chemicals depends on their **volatility** and water solubility. Aqueous phase chemicals, chemicals that are soluble in water, dissolve in and move with groundwater. Nonaqueous phase chemicals (NAPLs) do not dissolve in water and may be either lighter than water (light nonaqueous phase liquids or LNAPLs) or heavier than water (dense nonaqueous phase liquids or DNAPLs). The distinction between DNAPLs and LNAPLs has a significant impact on the detection and remediation of organic contamination.

volatile any substance that evaporates readily

LNAPLs such as petroleum products (e.g., gasoline, diesel, oils) are common contaminants in urban, industrial, and agricultural areas. DNAPLs such as chlorinated solvents—trichloroethylene (TCE) and perchloroethylene (PCE)—are found also in urban and industrial areas, most commonly in association with the dry cleaning industry, where previous management practices often resulted in the spilling or dumping of these chemicals. These NAPLs pool above (LNAPL) or below (DNAPL) groundwater bodies, dissolving slowly into, and potentially contaminating, enormous volumes of water. In states that rely heavily on **groundwater** for drinking water, billions of dollars have been spent in the last two decades to replace leaking underground gasoline storage tanks (LUSTs) and to clean up historical contamination.

When contamination is detected in groundwater, one common cleanup approach is to drill wells, then pump out and purify the contaminated water using a variety of methods, including **air stripping**, where compounds are **volatized** from the water into the air. This technique does not rid the environment of the pollutants, however, as the contaminants are merely transferred from the water to the air. Less volatile compounds, or those at low concentrations, may be removed by filtration through a solid **sorbent**, such as activated carbon. This "pump and treat" approach addresses only the dissolved, aqueous phase of contamination, while leaving the concentrated, nonaqueous "pool" as

groundwater the supply of freshwater found beneath the Earth's surface includes; aquifers, which supply wells and springs

air stripping a treatment system that removes volatile organic compounds (VOCs) from contaminated groundwater or surface water by forcing an airstream through the water and causing the compounds to evaporate

volatilize vaporize; become gaseous

sorbent a substance that absorbs (within) or adsorbs (on the surface) another substance

a continuing source of groundwater contamination. As a result, "pump and treat" may be a prolonged process. The detection and elimination of NAPL source zones of contamination are more desirable where feasible.

In order to remove sources of groundwater contamination, technologies are needed to accurately detect and measure the amounts of these chemicals. Well drilling is commonly used to investigate or remediate contaminated sites, though it is relatively slow and expensive, and it brings up contaminated soil that must be disposed of properly. Direct push technologies use large vehicles equipped with hydraulic rams or percussion equipment to push metal tubes into the ground. Special sensors on the advancing tip of these tubes provide information on the nature of the sediments being penetrated. Recent advances in this technology allow special chemical sensors to be deployed on the end of the tube providing information on the presence and concentration of chemicals in the ground. The hollow tube also can be used to collect soil and groundwater samples. When sampling is complete, the rods typically are removed from the ground and the hole is sealed. While depth and geology limit "direct push," it is generally faster than well drilling, and it does not contaminate the soil.

Once source zones have been identified, technologies may be deployed to remove contamination. One of the most popular approaches to removing NAPLs is thermal treatment. Heating contaminated soil and groundwater to the boiling point of the contaminant will convert liquids to gases, which move through the soil. Wells are used to extract the resulting gases that can then be absorbed by activated carbon, or heated to temperatures high enough to break them down into harmless elements. Typically, soils are heated in one of two ways: electrical resistance or steam injection. Electrical resistance heating uses **electrodes** placed in the ground between which electrical currents are passed. The soil's resistance to the movement of the electrical current produces heat. Steam heating pumps high-pressure steam into the ground through injection wells.

electrode conductor used to establish electrical contact with a substance by delivering electric current to it or receiving electric current from it

Conversion

Conversion uses chemical reactions to change contaminants into less toxic or less mobile forms. These chemical reactions may be produced by the introduction of **reactive chemicals** to the contaminated area, or by the action of living organisms such as bacteria.

reactive chemicals chemicals likely to undergo chemical reaction

The use of biological systems to clean up contamination is known as **bioremediation**. Bioremediation includes all cleanup technologies that take advantage of biological processes to remove contaminants from soil and groundwater; the most common technique is microbial metabolism. For decades, scientists have known that microbes can degrade certain organic contaminants, and in cases of historical contamination, microbial communities often adapt to take advantage of the energy released when these chemicals are degraded (i.e., metabolized). By studying the existing conditions, substances that microbes need to break down chemicals, such as nutrients or oxygen, may be added to enhance biodegradation. Microbial biodegradation is capable of degrading most organic contaminants.

bioremediation use of living organisms to clean up oil spills or remove other pollutants from soil, water, or wastewater; use of organisms such as nonharmful insects to remove agricultural pests or counteract diseases of trees, plants, and garden soil

For example, under ideal conditions, microbes can degrade the organic constituents of petroleum hydrocarbons such as gasoline or diesel fuel, to

carbon dioxide and water. This is the concept behind a technology being used by the U.S. Department of Energy to remove petroleum contamination from soils that also contain low levels of radioactive materials. The combination of hazardous materials (petroleum) and radiation places this soil in the regulatory category of mixed waste, for which disposal is extremely difficult. By using biodegradation to remove the petroleum component, the remaining soil can be classified as low-level radioactive waste, which has an accepted disposal mechanism.

A microbe discovered in the mud in the bottom of the Hudson River may solve the problem of treating groundwater contaminated with the industrial solvent TCA (trichloroethane). The microbe, which lives without oxygen, converts TCA into chloroethane, a compound that can more easily be removed from groundwater. The Environmental Protection Agency lists TCA as a contaminant of concern at 696 of its 1,430 priority cleanup sites.

Soils. Heavy metals are a common target for conversion approaches. Removal may not be practical when such metals contaminate large areas of surface soil. In these cases, chemical approaches often are sought to convert the metals to a less toxic and less mobile form. Such conversions often involve the use of reactive agents such as sulfur to create **immobile** sulfide salts of metals (e.g., mercury). Reducing the mobility of soil contaminants often refers to reducing the water solubility of the compounds. Reducing water solubility lowers the potential for contaminants to become dissolved in and move with water in the subsurface.

immobile not moving

Groundwater. DNAPLs such as chlorinated solvents may be treated with chemicals (e.g., potassium permanganate) that degrade the solvents into relatively harmless chemicals. When combined with chlorinated solvents, potassium permanganate removes chloride **ions**, which results in the degradation of these chemicals to carbon dioxide (CO_2) and water. This technology holds promise as a tool for remediating these challenging contaminants.

ion an electrically charged atom or group of atoms

Containment

Situations exist in which technologies are not available or practical to remove or convert contaminants. In those situations, it is often possible to contain the contamination as a final solution or as an interim measure until appropriate technologies become available.

Soils. Radionuclides from historical weapons production and nuclear testing, as well as from industrial uses of radiation, appear to be a good match for developing containment technologies. For example, containment is a promising technology for the management of radioactively contaminated soils beneath the large high-level radioactive waste storage tanks at the U.S. Department of Energy Hanford site in Washington State. Removing radioactive contamination from soil is problematic from a worker-safety standpoint, and it may create further contamination of equipment, containers, and surrounding areas. Efforts to develop effective physical containment technologies for soil contaminants are continuous.

Groundwater. Groundwater is not generally suitable for absolute containment; however, between containment and conversion is a technology known as reactive barriers. Reactive barriers intercept contaminated groundwater **plumes** and are constructed of chemically reactive materials (e.g., iron) that bind or convert dissolved contaminants. Reactions between the contaminant and the iron either immobilize or degrade the contaminant by altering its chemical form (redox manipulation).

plume a visible or measurable discharge of a contaminant from a given point of origin; can be visible, invisible, or thermal in water, or visible in the air as, for example, a plume of smoke

Passive Cleanup

Passive remediation technologies are increasingly common in some applications, and take advantage of naturally occurring chemical or biological

processes that degrade contaminants to less toxic forms. The accepted term for this group of technologies is monitored natural attenuation (MNA), which is the result of regulatory recognition that natural biological processes are capable of degrading certain contaminants under specific conditions and that dispersion may aid in achieving objectives. MNA is employed for the cleanup of organic contaminants such as petroleum hydrocarbons in situations where the longer time frame associated with MNA does not increase the risks posed by the contamination. MNA recognizes that, while these processes are possible, they must be monitored to insure that the expected progression actually occurs. In the State of Florida, MNA is being used as an approved cleanup action for some former dry cleaning sites. At these sites, natural processes are being monitored as they degrade chlorinated solvents from the former dry cleaning operations.

MNA is one example of major innovation in this area. Environmental cleanup is a dynamic field. Advances in science and engineering fuel innovative approaches and technologies, and advanced technologies provide greater capabilities in meeting the ultimate goal of a safer and healthier environment. SEE ALSO ABATEMENT; BIOREMEDIATION; DREDGING; ECONOMICS; INCINERATION; LAWS AND REGULATIONS, INTERNATIONAL; LAWS AND REGULATION, UNITED STATES; LOVE CANAL; NONAQUEOUS PHASE LIQUID (NAPL) SUPERFUND; TIMES BEACH; UNDERGROUND STORAGE TANK; WATER POLLUTION.

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J. Michael Kuperberg, Christopher M. Teaf, and Heather V. Ritchie

Climate Change *See Global Warming*

Coal

Coal is a brown-to-black combustible rock that originated from peat deposits in large swamp environments, through their burial to great depths and over a few hundred thousand to tens of millions of years. During burial peat is converted first into lignite, then subbituminous and bituminous coal, and, uncommonly, anthracite. Due to the loss of moisture during burial (peat has about 90 percent in its natural state, bituminous coal as little as 2 to 3 percent) and the chemical changes in the plant material that are induced by the rising temperature during burial to thousands of feet (increased carbon and decreased oxygen contents in particular), the heating value of coal increases significantly from peat to lignite and on to bituminous coal and anthracite.

The various environments that prevailed in the peat swamps (e.g., forests with large trees; marshes with sedges, grasses, and reeds) produced various kinds of peat and thus coal with significantly different properties. The major coal types—banded, nonbanded, and impure coal—are easily recognizable. Banded coals are most common. In subbituminous and bituminous coal the bands are composed of vitrain (shiny, glassy, brittle), clarain (bright luster, tough), durain (dull luster, hard), and fusain (charcoal-like, soft). Under the microscope, the so-called **macerals** become visible. Many of these clearly reveal their plant origin (e.g., sporinite, cutinite, resinite, alginite), whereas others have lost much or all of the plants' original cell structure (e.g., vitrinite, collinite, inertinite, semifusinite).

maceral organic remains visible in coal

Coal Mining and Pollution

Coal is recovered from the ground either by underground or surface mining. Underground mining creates voids over many square miles. Two basically different methods are used: longwall and room-and-pillar mining. In longwall mining all coal is recovered from the mined panels; hence, **subsidence** occurs at the surface almost immediately and it is planned for. Room-and-pillar mining leaves about half of the coal in the ground as pillars to support the surface and prevent subsidence. However, subsidence may still occur because coal pillars or the floor strata under them fail, sometimes decades after mining (this sort of unplanned subsidence is a significant problem in major coal-producing states of the past). Subsidence causes damage to structures and interferes with the drainage of surface water; it may also impact aquifers. Coal left in the ground may catch fire, for example, through spontaneous combustion. Mine fires are difficult to control; some have burned for decades, even centuries. They can cause considerable local pollution, as well as other problems. Coal also always contains methane (CH_4), most of which is released into the atmosphere during mining. On the average, the deeper a mine, the more methane it generates. Methane is a very potent greenhouse gas and contributes to global warming. Another significant environmental problem is related to underground mines that operated above the local drainage level. The **mine workings** collect and conduct water that oxidizes the ever-present pyrite (FeS_2) in coal-bearing strata and causes acid mine drainage into the local drainage system. This is a common problem in the mountainous Appalachian coal fields where many old mines were operated at shallow depth above valley floors.

subsidence sinking of earth surface due to underground collapse

mine workings the parts of a quarry or mine that is being excavated

For surface mining, large machines are used to remove all rocks and/or soil above the coal bed or beds to gain access to it or them (usually at depths of less than 150 to two hundred feet). Any surface drainage and aquifers in the **overburden** will be severely impacted within the vicinity of the mine pit. Also, the fertility of agricultural land becomes a concern. Modern mining laws require the careful monitoring of groundwater at mines and the restoration of proper drainage and fertility to farmland, to its premining levels, through **reclamation**. Contaminated water (e.g., water containing suspended fine solids and/or dissolved minerals) may run off the open pit and must be treated before release into the local drainage system.

overburden rock and soil cleared away before mining

reclamation in recycling: restoration of materials found in the waste stream to a beneficial use which may be for purposes other than the original use

Modern mining laws seek to remedy or minimize the above-mentioned environmental and other problems related to the mining and cleaning of coal, as well as many other related concerns. See the table for a listing of the top producers of coal by state.

LEADING COAL-PRODUCING STATES OF THE UNITED STATES

Rank	State	2001 Production
1	Wyoming	365.6
2	West Virginia	160.4
3	Kentucky	132.6
4	Pennsylvania	76.4
5	Texas	45.0
6	Montana	39.1
7	Indiana	37.1
8	Illinois	33.8
9	Colorado	33.4
10	Virginia	32.5
11	North Dakota	30.5
12	New Mexico	29.6
13	Utah	27.0
14	Ohio	25.3
15	Alabama	19.2
16	Arizona	13.4
	Other states	20.4
	U.S.A.	1,121.3

SOURCE: Adapted from U.S. Department of Energy.

Coal Cleaning and Pollution

Many mined coals, especially from eastern and Midwestern coal fields, contain significant mineral matter in their raw mined state—up to about half by weight—and they are cleaned before sale. Preparation plants, capable of cleaning or processing several million tons of coal a year, generate large quantities of refuse that must be disposed of locally, safely, and in an environmentally sound manner. The materials rejected by a cleaning plant tend to be enriched in iron sulfides (FeS_2: pyrite and marcasite) in particular; these oxidize easily into sulfates, causing the acidification of any water that percolates through and exits from refuse piles; acid water in turn tends to dissolve various other minerals, creating products that are potentially harmful to plants, animals, and humans. Cleaning plants always reject some coal, together with the incombustible material; spontaneous combustion can cause refuse piles to catch fire, which emit pollutants and are difficult to control.

Coal Utilization and Pollution

Coal, due to its origin from plants, is composed primarily of the "organic" elements carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S). Whenever coal is used, it eventually ends up being burned, either through direct combustion in boilers, for example, those in large electric utility power plants, or after conversion into intermediate products like **coke**. Of all the oxidation products of these elements, carbon dioxide (CO_2) has become a major concern because it is a powerful greenhouse gas that accumulates in the atmosphere and is considered the primary cause of global warming. Sulfur and nitrogen oxides (SO_2, NO_x), when released into the atmosphere from power plants, become a human health hazard and lead to the formation of acid rain downwind. This has been an important social and political issue for several decades, and various laws have been enacted that force power companies to limit the emission of sulfur and nitrogen oxides. All "new" (since 1970) electric power plants must remove most of the SO_2 from their flue gas, using various types of **scrubbers**. A cost-effective way to control SO_2 total emissions has been *emissions trading*, the federal government's decision to award a limited number of SO_2 "pollution allowances" to utilities that they are permitted to trade; this allows industry to decide at which plants it is most cost-effective to add scrubbers. The 1970 Clean Air Act (CAA) exempted existing power plants from this requirement, assuming that they would be shut down in the near future. To close this loophole, the 1977 CAA amendments established the "new source review" process (NSR), which requires a careful review of any changes performed in "old" (pre-1970) plants to determine whether they represent "routine maintenance, repair, and replacement" or a significant upgrading in which the plant would become subject to the same rules as new plants. Over the years these reviews became highly controversial because of the gray area between "routine maintenance" and "significant upgrading." In response, after a multiyear review process, the U.S. Environmental Protection Agency (EPA) proposed revisions of the regulations in late 2002, intending to overcome these widely recognized problems, provide greater flexibility for power companies to improve old plants, lead to increases in energy efficiency, and decrease pollution. However, environmental and political groups have challenged the proposed new regulations. One proposal to resolve the controversy would be to abolish the NSR

coke carbon fuel, typically derived from bituminous coal, used in blast furnaces for the conversion of iron ore into iron

scrubber an air pollution device that uses a spray of water or reactant or a dry process to trap pollutants in emissions

process entirely and expand the pollution allowances trading system to old power plants. By capping the number of allowances over time, total pollution could be further lowered.

Besides these major elements, coal always contains a large number of other elements in minor and trace amounts. Some of these are highly toxic, for instance, mercury (Hg), arsenic (As), cadmium (Cd), lead (Pb), selenium (Se), and uranium (U). Because coal is burned in such large quantities, primarily to generate electricity (nearly a billion tons in the United States alone!), even trace amounts add up to large quantities being released into the atmosphere. The 1990 Amendments to the Clean Air Act identify 189 *hazardous air pollutants* (HAPs), eighteen of which are associated with coal. Of particular concern are those elements that form volatile compounds during coal burning and are carried into the atmosphere with the flue gas. The 1990 amendments require the EPA to study the health effects of HAPs and develop appropriate regulations for their control.

Even cleaned coal still contains incombustible minerals (about 5 to 15 percent by weight) that are converted into ash when coal is burned at very high temperatures. Some ash particles are small and light enough to be carried up tall chimneys into the atmosphere with the flue gas (fly ash). Most power plants are required to remove fly ash from flue gas, using bag houses or electric precipitators. Both methods are highly efficient. However, tiny particles (**PM-10**) may still escape. Because of their potential harm to humans, they have been targeted for regulation in recent years. Coarser-grained ash remains at the bottom of boilers (bottom ash); it is removed and disposed of nearby. Fortunately, this material is rather inert and of limited environmental concern. SEE ALSO Acid Rain; Air Pollution; Carbon Dioxide; Electric Power; Emissions Trading; Fossil Fuels; Global Warming; Greenhouse Gases; Methane; NO_x (Nitrogen Oxides); Particulates; Scrubbers.

PM-10 airborne particles under 10 micrometers in diameter

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Heinz H. Damberger

Colborn, Theo

AMERICAN ENVIRONMENTALIST, COAUTHOR OF *OUR STOLEN FUTURE*
(1927–)

Dr. Theo Colborn focused international attention on the dangers of endocrine disrupters, chemicals that alter or block **endocrine** functions.

endocrine the system of glands, hormones, and receptors that help control animal function

With Dianne Dumanoski and John P. Myers, she authored *Our Stolen Future*, published in 1996. This seminal work synthesizes scientific evidence, gleaned from Colborn's seven years of research review, on the dangers of hormone-disrupting chemicals.

Small amounts of these chemicals are especially dangerous for fetuses and infants because hormones control all aspects of development such as organ and physiological system development, sexuality and reproductivity, learning and behavior. *Our Stolen Future* led to congressional legislation aimed at protecting children from such exposure. It also motivated much scientific research on potential hormone-disrupting chemicals, such as phthalates, bisphenol-A, and numerous fire retardants.

Colborn was born in Plainfield, New Jersey in March 1927. She raised four children while working as a pharmacist but became increasingly interested in environmental issues. At age 51, she enrolled as a graduate student in ecology, studying stone flies and mayflies as indicators of stream health. She received a Ph.D. in zoology from the University of Wisconsin in Madison in 1985. Her first job, as a congressional fellow at the Office of Technology Assessment in Washington, involved working on studies related to air pollution and water purification. She joined the Conservation Foundation, a nonprofit think tank in 1987. Her job there, scientifically assessing the health of the Great Lakes, resulted in *Our Stolen Future.* Colborn is a senior scientist with the World Wildlife Fund and travels widely, speaking about the dangers of prenatal exposure to chemicals that interfere with hormonal systems. SEE ALSO ENDOCRINE DISRUPTION.

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Patricia Hemminger

Combined Sewer Overflows (CSOs) *See Wastewater Treatment*

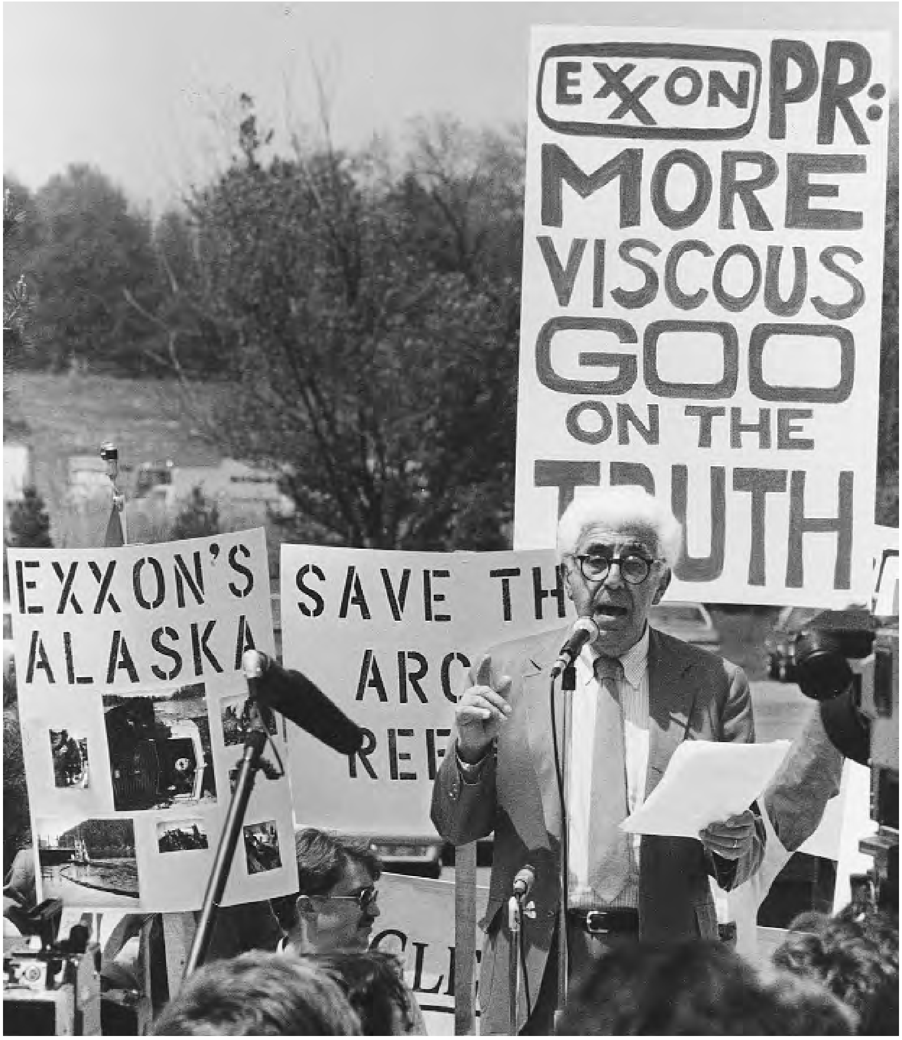
Commoner, Barry

AMERICAN ENVIRONMENTALIST, WRITER, AND PROFESSOR OF BIOLOGY
(1917–)

Barry Commoner's 1971 book *The Closing Circle: Man, Nature and Technology* attempted to explain the causes of and solutions for environmental degradation in modern society. The "closing circle" was his metaphor for the connection between humans and the natural ecosystem.

Commoner argued that there were three possible causes of environmental degradation: human population growth, increasing affluence, and modern technology. He concluded that modern technology was the principal cause of society's environmental problems. This opinion put him at odds with Paul Ehrlich, who had argued in his 1968 book, *The Population Bomb*, that human overpopulation was the principal cause of environmental problems.

The Closing Circle never offered a definitive solution to the problems it presented, however. A memorable idea in the book is its four laws of ecology:



Barry Commoner speaks to protesters outside a hotel in New Jersey where Exxon stockholders met in 1989. (Corbis-Bettmann. Reproduced by permission.)

(1) everything is connected to everything else; (2) everything must go somewhere; (3) nature knows best; and (4) there is no such thing as a free lunch.

Commoner has generally favored leftist political causes and, in 1980, he ran for U.S. president on the Citizen's Party ticket. He has been the recipient of eleven honorary university degrees and has served on the boards of numerous environmental and antiwar organizations. On May 30, 1997, a symposium titled "Barry Commoner's Contribution to the Environmental Movement" was held in honor of his eightieth birthday. SEE ALSO EHRLICH, PAUL.

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Joseph E. de Steiguer

Composting

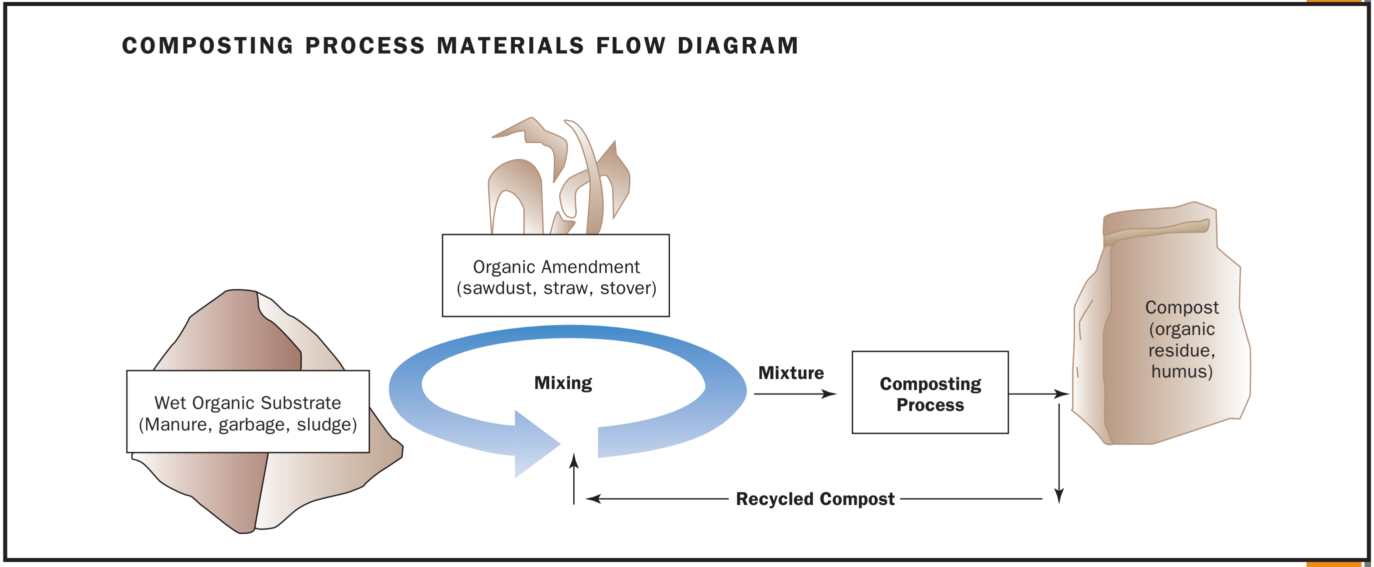
Decomposed biosolids (e.g., leaves, crop residue, animal waste) have long been used to recycle plant nutrients and enhance soil fertility. It is one of the

humus rich soil component derived from plant breakdown and bacterial action

most ancient of agricultural innovations, as is evidenced by an ancient Telgu proverb "Leaf manure produces luxuriant growth" (Donahue *et al.*, p. 154). Despite its long history, the scientific principles and systematic explanation of the techniques involved were not described until 1935 when Sir Albert Howard, working in Indore, Madya Pradesh, India, described the so-called Indore method of composting in which plant and animal waste is converted into **humus**. The process was developed between 1924 and 1931 for two reasons: to eradicate parasites from biosolids and maintain soil fertility. It was realized that "improved varieties by themselves could be relied upon to give an increased yield in the neighborhood of 10 percent, improved varieties plus better soil conditions were found to produce an increment up to 100 percent, or even more" (Howard, p. 39). The process involves creating an admixture of animal and plant wastes with a base for neutralizing acidity, and managing the admixture so that microbial processes are most effective at humifying the biosolids. The fermenting processes are allowed to occur in a shallow pit to avoid loss of water. The pit is surrounded by a cutoff drain to prevent run on and by a thatch of roof to keep rains out and reduce the risk of inundation.

Thus, composting is the biological reduction of biosolids into a soil-like, nutrient-rich material. The composted product is safe and easy to handle, and does not induce nitrogen deficiency in recipient plants by nitrogen stabilization in the compost. It suppresses disease infestation by partial sterilization and detoxifies pollutants. Principal types of organic wastes used in composting are animal manure, yard waste, municipal solid waste, paper mill sludge, municipal sewage, and fermentation waste. An important precaution when creating a usable end product is to exclude those materials that contain weed seed or cuttings which may sprout and become weed, or infested material that may spread pathogens to recipient crops. These organic materials are decomposed into humus outside of the soil by a process called humification that normally occurs within the soil. The application of biosolids directly to soil may have adverse impacts on soil quality and plant growth. With decomposition of biosolids and their humification the compost pit minimizes the adverse impacts. Techniques have also been developed for making satisfactory compost from sewage sludge. Of concern here is the risk that heavy metals in municipal sludge will contaminate cropland.

Composting is a hygienic way of recycling nutrients in the organic by-products of agriculture, urban, and industrial activities. It represents safe storage and easy handling, and is an economic source of plant nutrients. It is an important strategy for handling a significant volume of by-products. The quantity of biosolids available for composting in the United States is large (see table). Properly used, it is a major resource for enhancing soil quality and improving environments. Compost material is principally used for the reclamation of drastically disturbed (e.g., mined) soil and other degraded ecosystems, and for landscaping and agriculture. Rather than cause environmental pollution, properly composted organic material can be a major asset in the enhancement of soil fertility, restoration of degraded soils, and sequestration of carbon. Carbon sequestration implies removal of carbon dioxide from the atmosphere either biotically through photosynthesis as plant products or abiotically by capturing from industrial sources. Subsequent storage of the carbon thus captured into long-lived pools such as soil, forestry products, geological strata, or ocean.



Process of Composting

The humification of organic material under most conditions occurs in three stages:

1. *Mesophilic stage.* This is the initial stage of decomposition, lasting for about a week, during which sugars and other simple carbohydrates are rapidly metabolized. This is an **exothermic** process and may cause an increase in temperature by 40°C.
2. *Thermophilic stage.* This is the second stage, lasting for about two weeks, during which the temperature may rise to about 50 to 75°C. Such a drastic increase in temperature is accompanied by the decomposition of cellulose and other resistant materials. It is important that the material be thoroughly mixed and kept **aerated** during this stage.
3. *Curing stage.* The temperature decreases during this final stage and the material being composted is recolonized by mesophillic organisms, which often produce plant-growth stimulating compounds. Mesophillic organisms are usually fungal-dominated and useful to restore bacteria dominated soils.

exothermic releasing heat

aerate process of injecting air into water

At the completion of this process, the plant or other organic parts (leaves, roots, etc.) are no longer identifiable in the compost. The humification of organic material is characterized by an increase in concentration of humic acids from approximately 4 to 12 percent, and a decrease in the C/N ratio from thirty in the original material to about ten in the final product.

Composting Techniques

Traditionally, composting has been an important technique for maintaining soil fertility. In developed economies, composting is a commercial enterprise, manufacturing soil products for horticultural and ornamental plants, and organic farming. On a small scale, composting is done in a bin at least 1 m^2 at the base and no more than 120 cm (4 feet) high. A 5-cm mesh of woven wire is placed at the base of the bin as a retaining barrier and to facilitate drainage. The bin has an overflow gate at about 90 cm from the base.

ESTIMATES OF POTENTIALLY COMPOSTABLE ORGANIC MATERIALS IN THE UNITED STATES

Source	Amount generated (Mt/yr)
I. Agriculture and forestry	
(i) Farm manure, crop residues, animal carcasses	590
(ii) Logging and wood manufacture (bark, chips, sawdust, scraps)	55
II. Municipal waste	
(i) Paper, cloth, yard refuse, leaves, garbage, landscape, refuse, wood	125
(ii) Municipal sewage sludge (biosolids)	9
(iii) Domestic septic tank sludge	3
III. Industrial by-products	
(i) Petroleum, paper, food processing wastes, textile, pharmaceutical	45
(ii) Hydrocarbon-contaminated soil, pesticide waste	50
Total	877

SOURCE: Adapted from Barker, 1997.

Composting material is packed in the bin in approximately 15-cm layers, alternated by 15-cm layers of soil. It is important to flatten the top and create a small depression for water penetration. Small-scale backyard composting is an effective way to recycle food and yard waste.

Precautionary measures that should be taken include the following:

- provide good aeration throughout the pile;
- avoid excessive packing;
- avoid weed seeds, rhizomatous, and disease-infested materials;
- do not use by-products containing heavy metals and other contaminants;
- build pile large enough to generate sufficient heat;
- keep the pile moist at 50 to 70 percent moisture content;
- provide a coarse mesh screen at the base of the bin; and
- mix bulking agents such as wood chips and residue.

The compost is usually ready within three to four months. SEE ALSO AGRICULTURE; BIOSOLIDS; RECYCLING.

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Rattan Lal

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was established in 1980 by Congress. CERCLA's objective was to provide a regulatory mechanism in response to threats to human health or the environment from abandoned hazardous waste sites. Passage of CERCLA was heavily influenced by events at Love Canal, New York, where toxic chemicals oozing from an abandoned hazardous waste dump forced the abandonment of homes and a public school. Under CERCLA, the Environmental Protection Agency (EPA) was given funds and the authority to clean up such sites when a responsible party could not be identified. The funds were derived from taxes on industry, particularly the oil and chemical industries, and became known as Superfund.

CERCLA's major provisions establish (1) liability for hazardous waste cleanup by the generator of the waste; (2) a system for EPA to rank hazardous waste sites; (3) a national priorities list for the sites eligible for cleanup through Superfund; (4) and a national contingency plan that details the procedures to be followed to assess contamination at a site, the degree of hazard to public health or the environment, pathways for pollutant movement, alternatives to clean up a site, and the record of decision by EPA detailing how the site is to be remediated.

In 1986, the Superfund Amendments and Reauthorization Act (SARA) amended CERCLA. SARA provided an additional $8.5 billion for cleanup of hazardous waste sites and emphasized the need for faster cleanups and permanent remediation practices. Also, under SARA, EPA was given authority to enforce hazardous waste regulations at many government facilities operated by the Department of Defense and the Department of Energy.

In 1986, residents of Woburn, Massachusetts, relied on CERCLA's provisions to bring a lawsuit against potentially responsible parties for the contamination of drinking water wells located in the city of Woburn. The lawsuit claimed that three industries were responsible for contaminating the city's wells and were therefore liable for cleanup of the drinking water and for damages to residents. The suit claimed that an abnormally high incidence of leukemia in Woburn was the result of consumption of contaminated drinking water from the city's wells. One company was found not guilty while another settled for $8 million with no admission of wrongdoing. This case was depicted in *A Civil Action*, later made into a Hollywood film.

Hazardous waste legislation exists in most countries in the industrialized world; however, differences exist regarding the relative authority and oversight of central and local governments and liability of the waste generator after disposal of the waste. SEE ALSO BROWNFIELD; CLEANUP; HAZARDOUS WASTE; LAWS AND REGULATIONS, UNITED STATES; SUPERFUND.

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Thomas D. DiStefano

Concentrated Animal Feeding Operations (CAFOs)

See Agriculture

Conferences

See Treaties and Conferences

Consensus Building

Consensus building addresses conflict by helping disputants themselves decide the process and the outcome. It involves a number of collaborative decision-making techniques and an impartial facilitator or mediator is often used to assist diverse or competing interest groups to reach agreement on policy matters, environmental conflicts, or other issues in controversy affecting a large number of people. The processes include negotiation, facilitation, **mediation**, and regulatory negotiation (including public policy negotiation). Consensus building processes are typically used to foster dialogue, clarify areas of agreement and disagreement, improve the information on which a decision may be based, and resolve controversial issues in ways that all interests find acceptable. The goal is to produce sound policies or agreements with a wide range of support while reducing the likelihood of subsequent disagreements or legal challenges. Disputes over the interpretation or application of rules may be resolved through consensual or **adjudicative** means, and in some cases through coercion or force by legislation. Adjudicative dispute resolution means that a third party makes a binding decision for the parties. Adjudicative approaches include arbitration and court adjudication. Legislative approaches to dispute resolution focus on rule-making by a group, organization, formal legislative body, or ruler. SEE ALSO ARBITRATION; ENFORCEMENT; GOVERNMENT; LEGISLATIVE PROCESS; LITIGATION; MEDIATION; PUBLIC POLICY DECISION MAKING; REGULATORY NEGOTIATION.

mediation dispute resolution in which a neutral third party helps negotiate a settlement

adjudicative involving the court system

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Susan L. Senecah

Consumer Pollution

Consumer pollution refers, in part, to traces of numerous consumer products, including pain relievers, prescription drugs, antibiotics, insect repellent, sunscreens, and fragrances—collectively called pharmaceuticals and personal care products (PPCPs)—discovered in inland and ocean waters. Between 1999 and 2000 the United States Geological Survey (USGS) established the widespread occurrence in the environment of minute but measurable quantities of PPCPs, along with other organic wastewater contaminants, such as detergent **metabolites**, plasticizers, and fire retardants. These contaminants were discovered in 80 percent of 139 waterways downstream from sewage treatment plants and livestock operations. Before 1999 most research into PPCPs took place in Europe, and pharmaceuticals were detected there in sewage treatment effluent, surface water, groundwater, drinking water, and the North Sea.

metabolite any substance produced by biological processes, such as those from pesticides

How PPCPs Enter the Environment

Thousands of PPCPs are consumed worldwide, some on a par with agrochemicals, at rates of thousands of tons a year. These substances enter the environment largely from sewage treatment plants, as well as directly from fish farms, storm runoff, recreational activities, and leaking landfills. Incompletely metabolized drugs or their metabolites—chemicals formed from the body's interaction with the drug—are excreted in the urine and feces of humans and animals. Cosmetics and perfumes are washed off in the shower. Unused drugs are flushed down the toilet or thrown out in the trash. Antibiotics, steroids, and other drugs that are used to treat animals, such as those in confined animal feeding operations, are eventually washed into sewer drains or directly into local waters from roads and farms.

Sewage is treated to break down human waste, but the wide occurrence of eighty-two out of the ninety-five substances tested for in the USGS survey indicates that many synthetic chemicals are not completely removed by sewage treatment methods. PPCPs in wastewater effluent end up in rivers, lakes, and oceans, and contaminants in manure or sewage sludge are spread on land.

Potential Health and Environmental Effects

The concentrations of PPCPs found in the USGS survey range from parts per trillion (ppt) to parts per billion (ppb), or nanograms per liter to micrograms per liter. For pharmaceuticals this is many orders of magnitude below the concentrations prescribed as medication.

However, some PPCPs, such as musk fragrances, are fat soluble and so can bioaccumulate in animal tissue. In addition, many water-soluble PPCPs are effectively persistent if they are continually replenished from sewage effluent. Fish and other aquatic species could therefore be permanently exposed to these chemicals. Although research on the environmental effect of PPCPs is sparse, some studies link low concentrations of oral contraceptives, along with reproductive estrogens, to the feminization of male fish. When exposed to the estrogens, male fish produce vitellogenin, an egg protein, usually found only in the females. Other studies show that fluoxetine, marketed as Prozac, affects reproductive hormonal activity in zebra mussels, crayfish, and fiddler crabs. Some scientists think that aquatic species could be harmed

FREQUENCY OF DETECTION OF PPCPS IN STREAMS

Percentage of streams in which contaminant was found	Category of contaminant	Representative substances found (median concentration, in ppb)
89%	Steroids	Cholesterol (0.83), coprostanol (fecal steroid) (0.88)
81%	Nonprescription drugs	Acetaminophen (0.11), caffeine (0.081), ibuprofen (0.2), cotinine (nicotine metabolite) (0.05)
74%	Insect repellent	DEET (0.06)
66%	Disinfectants	Phenol (0.04), triclosan (0.14)
48%	Antibiotics	Erythromycin metabolite (0.1), ciproflaxin (0.02), sulfamethoxazole (0.15)
37%	Reproductive hormones	17-alpha-ethynyl estradiol (0.073) (birth control), estrone (0.027)
32%	Other prescription drugs	Codeine (0.012), dehydronifedipine (antianginal) (0.012), diltiazem (0.021) (antihypertensive), fluoxetine (0.012) (antidepressant)
27%	Fragrances	Acetophenone (0.15)

SOURCE: Frequency of Detection of PPCPs in Streams. (2002). "Pharmaceuticals, Hormones and Other Organic Wastewater Contaminants in U.S. Streams. 1999–2000: A National Reconnaissance." *Environmental Science and Technology* 36, no. 6:202–1211

efflux pump inhibitor a drug that prevents a cell from expelling another drug; used with antibiotics to increase their effectiveness

more by pollutants if they are exposed to **efflux pump inhibitors** (EPIs). EPIs decrease the cell's ability to expel potentially harmful substances and are prescribed to help drugs pass through cell walls.

Another concern is that fish and other species constantly exposed to mixtures of low levels of PPCPs will be affected in small, undetectable ways that lead to irreversible changes over time. Such small shifts in behavior, immunology, and reproduction may be attributed to natural adaptation and may not be recognized as a consequence of pollution. Seventy-five percent of streams in the USGS survey contained more than one contaminant, and 13 percent contained more than twenty.

The presence of antibiotics in 48 percent of the streams and potentially in soil that is overlaid with sewage sludge could be a factor in the increase in antibiotic resistant strains of bacteria.

There is also a potential threat to human health. Recharging groundwater from surface water constantly infused with treated sewage effluent could result in PPCP contamination in drinking water. Some pharmaceuticals, including clofibric acid, have been detected in parts per trillion in drinking water in Germany. Clofibric acid is a metabolite of drugs taken by many people to reduce cholesterol levels in the blood. The long-term effect of swallowing very low, subtherapeutic amounts of multiple medications simultaneously many times a day for a lifetime is unknown.

Current and Proposed Research

Scientists in Germany are researching treatment methods to remove PPCPs from wastewater before it enters rivers and oceans, and from potable water. Results to date show that ozone treatment and/or filtering water through granular activated carbon effectively removes the pharmaceuticals commonly found in drinking water in Berlin.

Research in the United States in 2002 is aimed at establishing where and in what concentration organic wastewater contaminants, including PPCPs,

are found. PPCPs are not currently part of any water-monitoring program in the United States. The USGS is conducting a survey of these contaminants in groundwater and in sources of drinking water. Other research is focused on the presence of pharmaceuticals, including anticancer drugs and anticonvulsants in wastewater and drinking water.

Some scientists are proposing research to find out which PPCPs are harmful, especially to aquatic species, and how these chemicals work at the molecular level. Scientists also want to study whether exposure to a combination of different pharmaceuticals at low concentrations, especially those that work in the same way, poses a risk to humans or wildlife. Research is needed to develop analytical methods sensitive enough to detect traces of all the different pharmaceuticals and active ingredients in personal care products and to develop new ways for measuring subtle rather than acute toxic environmental changes.

Prevention and Recycling / Reuse

Source reduction, recycling, and replacement with "green" pharmaceuticals could help reduce excess or unused, expired medications. Disposal advice on packaging could recommend that drugs be recycled or disposed of in a controlled manner. Reducing the number of pills per container could reduce the amount of expired medication. Drug manufacturers could also find ways to minimize excess expired inventory.

Regulations

In the United States, the Food and Drug Administration requires an environmental assessment for new drugs when manufacturers predict that one ppb or more will enter the environment. The drug is then tested for acute toxicity, such as whether it causes cancer. Although most individual contaminants measured in the USGS study had concentrations below one ppb, the maximum total concentration of the thirty-three suspected or known hormonally active compounds was fifty-seven ppb. Some scientists argue that individual concentrations may not be significant for predicting risk, but concentrations of all drugs that behave in the same way should be considered.

Health Canada is at the beginning of a regulatory process that will require environmental assessment of products regulated under Canada's Food and Drug Act.

In Europe, since 1998, pharmaceuticals used in veterinary medicine must be tested for their environmental effect before they can be registered, unless the concentration predicted to enter groundwater is less than 0.1 ppb or less than ten ppb for drugs in soil. Similar standards are being considered for regulating pharmaceuticals taken by humans. Testing includes checking for inhibited algal growth, for acute, chronic, or bioaccumulation exposure in fish, for reproductive changes in birds, for earthworm toxicity, and for plant growth. SEE ALSO Endocrine Disruption; Health, Human; Non-Point Source Pollution; Sewage Studies; Toxicology; U.S. Food and Drug Administration (FDA); Wastewater Treatment; Water Pollution; Water Treatment.

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Patricia Hemminger

Coral Bleaching *See Water Pollution: Marine*

Cost-benefit Analysis

Cost-benefit analysis (C-BA) is a form of economic analysis in which costs and benefits are quantified and compared. C-BA is used primarily to evaluate public expenditure decisions with regard to such factors as esthetics, ethics, and long-term environmental costs (e.g., pollution costs).

Origins in the 1930s

C-BA had its origins in 1936 with the dam projects of the Works Progress Administration (WPA) in the western United States. At the time the federal government's policy was that projects would only be started if accrued benefits exceeded accrued costs. Although such a statement would be judged quite simplistic by today's standards, this philosophy is still the basis for C-BA.

Costs vs. benefits. The power of C-BA lies in its ability to organize and evaluate an action's likely effects and overall impact on economic welfare. CB-A states that if a project is to proceed on a successful basis, then total benefits should outweigh total costs. Consider, for instance, the following hypothetical scenario. The construction of an industrial complex next to an existing residential community will provide a needed boost to the community, which has a high unemployment rate. However, the new businesses will also cause substantial localized air and water pollution. CB-A will sum up all the benefits and costs in order to determine whether the new arrangement will be positive or negative for local residents and businesses.

Evolution into a Sophisticated Technique

C-BA has evolved into a highly technical subject, which normally requires that all costs and benefits (whether tangible or intangible) be expressed in monetary units. Tangible means that costs and benefits are capable of being understood and evaluated. An example of a tangible cost is the price of land for locating a new company. Intangible means just the opposite, that the economic costs and benefits are difficult to define clearly. The measurement of intangibles causes the most difficulty for C-BA. Pollution is one such intangible that is exceptionally difficult to measure because of its unique problems. For example, it is not easy to determine the value of clean air vs. degraded air quality due to pollution from a proposed manufacturing complex.

A number of sophisticated techniques have been developed to successfully measure such intangibles as pollution. In the earlier hypothetical case, one such technique estimates how much an individual is willing to pay to use

or retain clean air. Another technique is a subsidy offered to individuals to live with polluted instead of clean air. A third technique involves the measure of today's intrinsic value of clean air vs. the future costs of remedying the consequences of polluted air (such as respiratory problems and environmental cleanup).

Oklawaha River Canal

A good example of C-BA with respect to pollution was a 1962 U.S. Army Corps of Engineers proposal for a 177-kilometer (110-mile) canal to be dug across central Florida. The canal would have provided a shortcut for barge traffic from Texas and Louisiana to the Atlantic Coast by, in part, expanding 80 kilometers (50 miles) of the pristine Oklawaha River. Numerous citizen and environmental groups opposed the canal, citing the pollution and general environmental degradation it could potentially cause.

To the Rescue. A C-BA was undertaken with respect to various interest groups that would be affected, such as shippers using the canal and fishers using the river. The analysis determined that few benefits would be realized, and that the proposed project would be detrimental to most interest groups. Because of the evidence provided by the C-BA, the project was halted in 1971 by a citizen's group lawsuit and a presidential executive order.

Although C-BA has many strengths as a tool, it also has numerous weaknesses such as the inability to conclude anything without the use of financial costs and benefits and the inherent problem of introducing uncertainty of data when using intangible items unable to be analyzed even with sophisticated techniques. Even so, it is still a valuable tool for governments to consider in making decisions about the most effective use of their resources. C-BA can gather all the essential data related to an issue and establish reasonable economic, demographic, and technical assumptions that will serve as the ground-rules for the ensuing debate. C-BA is thus an important ingredient in the decision-making process concerning proposed projects that impact the environment and, especially, pollution.

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William Arthur Atkins

Jacques Cousteau. (AP/Wide World Photos/The Cousteau Society. Reproduced by permission.)

Cousteau, Jacques

MARINE ENVIRONMENTAL PROTECTION ADVOCATE (1910–1997)

Jacques Yves Cousteau was the twentieth century's best-known advocate for marine environmental protection. He produced 115 documentary films and television programs about adventures on his research ship, *Calypso*. He was also the coinventor of the aqualung or "scuba" tank.

Cousteau achieved international fame with his role as narrator and star of the television series *The Undersea World of Jacques Cousteau*. During his lifetime, he received numerous awards and honors. Among them were three Oscars and ten Emmy Awards for his films and television programs and the U.N.'s International Environmental Prize in 1977.

Cousteau trained as a pilot at the French naval academy, but injuries from an auto accident in 1933 prevented him from pursuing an aviation career. Soon thereafter he developed an interest in the undersea world and became obsessed with developing snorkels, bodysuits, and other diving gear. In the early 1940s he worked with a Parisian engineer to invent a regulator for a compressed air tank, a self-contained apparatus that allowed free movement and breathing underwater. Scuba diving was thus born.

Scuba was a great improvement over the heavy diving suits used at the time. Cousteau used scuba to help the French resistance during World War II and was awarded the Légion d'Honneur for his service. After the war, Cousteau developed scuba diving as part of a French naval research group. He also wanted to challenge age-old superstitions and open the undersea world to scientific exploration.

Cousteau was initially known for his 1953 best-selling book *The Silent World*. A film by the same title won a 1957 Academy Award for best documentary. Cousteau became director of the Oceanographic Institute of Monaco and, in that position, led a successful campaign to stop nuclear waste dumping in the Mediterranean. He also established experiments on deep undersea living near the continental shelf called Conshelf I, II, and III. Much of his environmental work was conducted by an organization he founded in 1973, the Cousteau Society. SEE ALSO OCEAN DUMPING.

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William Kovarik

Cryptosporidiosis

Cryptosporidiosis (also referred to as Crypto) is a gastrointestinal illness that results from exposure to the organism *Cryptosporidium parvum* (*C. parvum*). Cryptosporidiosis rose to public attention in the United States in 1993 when more than 100 people died and more than 400,000 people were sickened by Crypto in Milwaukee, Wisconsin.

Cryptosporidiosis is primarily a waterborne illness. People get infected from drinking inadequately treated drinking water, or from swallowing or drinking untreated water from a lake, stream, or swallowing water from a recreational swimming pool. People can become infected with Crypto through contact with the contaminated **fecal matter** of humans or animals carrying the organism, usually by swallowing food or liquid that has had contact with the contaminated fecal matter. Children at day care centers, day care workers, and health care workers interacting with infected individuals must be vigilant about sanitation to reduce the spread of the organism. Unwashed fruits and vegetables that have been in contact with Crypto-infected soil have also exposed people to the organism. Cattle and calves contribute significant amounts of Crypto to soils and adjacent water bodies; and wild animals such as elk, deer, bear, and beaver can also carry and spread the organism.

fecal matter animal or human excrement

Crypto's symptoms in humans are not unique. They include upset stomach, diarrhea, cramps, weight loss, dehydration, and sometimes fever. Some people do not experience any symptoms. The effects of cryptosporidiosis can be fatal for **immunocompromised** individuals, including AIDS and cancer patients. Cryptosporidiosis can only be diagnosed by testing a person's stool for the parasite. There is currently no treatment for the illness, which can last several days to a few weeks in healthy individuals.

immunocompromised having a weakened immune system

The organism, *C. parvum*, is miniscule. It is 3 to 5 microns in size, while the diameter of a human hair is 50 to 200 microns. *Giardia lamblia*, another significant waterborne parasite, is 5 to 7 microns in size.

Drinking water regulations that went into effect in 1990 focused on the removal and inactivation of Giardia. The threat of Giardia is removed by common water treatment practices, including filtration and disinfection with chlorine. These treatment practices are not as effective against Crypto, which is half the size of Giardia and resistant to disinfection with chlorine. Because drinking water containing *Cryptosporidium* is difficult to treat, it is important to protect the source of the water against animal waste runoff and other sources of Crypto contamination. Water treatment regulations in effect in 2002 require water utilities to improve treatment plant performance and consistency against *Cryptosporidium*. The revised drinking water regulations only address exposure from public drinking water sources; they do not address recreational waterborne exposure, or other routes of exposure that tend to be more common. SEE ALSO Health, Human; Risk; Water Pollution; Water Treatment.

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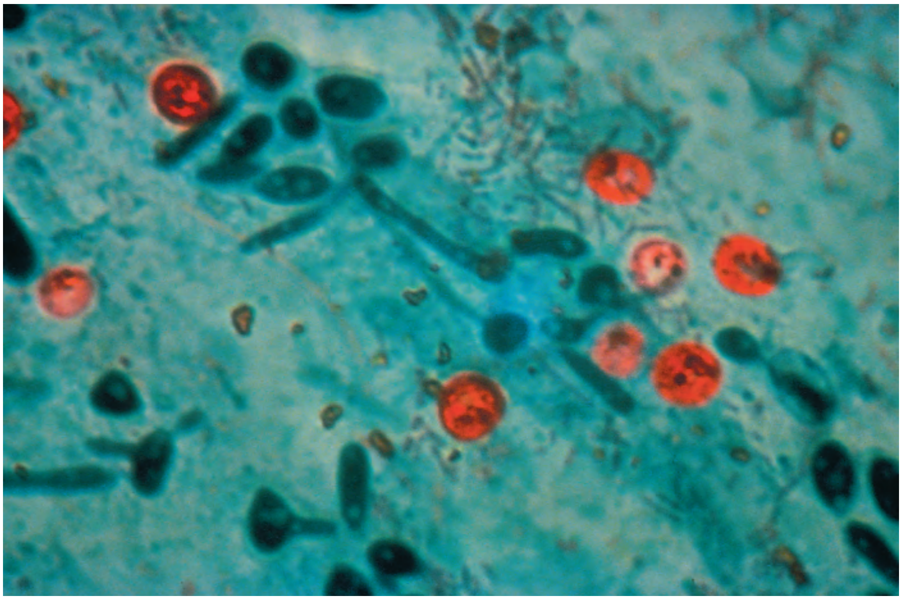

Cryptosporidium cells, which cause cryptosporidiosis. The infection is probably via fecal-oral transmissions from kittens and puppies. Those with suppressed immune systems are susceptible to diarrhea. (©Lester V. Bergman/Corbis. Reproduced by permission.)

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Julie Hutchins Cairn

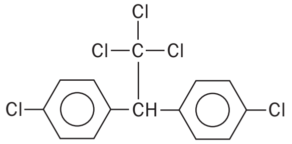
CSOs *See Wastewater Treatment*

D

DDT (Dichlorodiphenyl trichloroethane)

DDT, dichlorodiphenyl trichloroethane, was synthesized in 1874, but its insecticidal properties were first identified in 1939 by P.H. Mueller. He received the Nobel Prize for his discovery, which coincided with the outbreak of World War II, when DDT was used extensively to keep soldiers free of head and body lice. DDT also proved very effective against mosquitoes, which transmit a serious global human disease, malaria, as well as yellow fever. After the war, DDT was developed extensively as an agricultural pesticide.

DDT has an extremely low volatility and may be the least soluble chemical known, which makes it extremely persistent in soils and aquatic sediments. It has relatively low acute mammalian toxicity and is toxic to a wide range of insects. It kills insects by affecting the transmission of nerve impulses, probably by influencing the delicate balance of sodium and potassium within the neuron.



Chemical structure of DDT.

More than four billion pounds of DDT have been used throughout the world since 1940. Production in the United States peaked in 1961 when 160 million pounds were manufactured. Large economic benefits have resulted from the control of many serious agricultural and forestry pests, including Colorado potato beetle, cotton boll weevil, and pests of fruit, vegetables, corn, and tobacco. In forestry, its greatest success occurred in combating

A comparison of a normal Peregrine falcon eggshell and one thinned by exposure to the pesticide DDT. (©Galen Rowell/Corbis. Reproduced by permission.)

spruce budworm and gypsy moth. However, its major impact lay in the control of mosquitoes that transmit malaria, as well as body lice and fleas; many millions of lives have been saved through these uses.

DDT's potentially adverse environmental effects were brought to public attention by Rachel Carson in her book *Silent Spring* (1963). Carson emphasized the great persistence of DDT in soils and river sediments and focused on the bioconcentration of DDT through the trophic levels of food chains. One result of the bioaccumulation of DDT was the thinning of the eggshells of predatory birds such as bald eagles, peregrine falcons, golden eagles, hawks, and pelicans, resulting in embryonic death and decreasing populations of these species. DDT bioconcentrates because it has low water solubility and high fat solubility, that is, a high lipid-to-water partition coefficient (e.g., it can concentrate into fatty tissues from water). In the 1960s large DDT residues in human tissues and human milk began to be reported, probably from the consumption of food containing traces of DDT. DDT in body fat was reported to cause convulsions in laboratory rats; it also reached human fetuses by crossing the placenta. However, few serious effects on human health were officially recorded.

Many pests began to develop resistance to DDT, necessitating the progressive use of more of the pesticide to control such pests. In 1972 the use of DDT in the United States was banned on environmental grounds, including the widespread contamination of the environment with DDT, its ability to bioconcentrate, and its effects on endangered bird species.

Suitable alternatives to DDT were found in the United States and other industrialized countries that also banned its use in the 1970s. However, tropical developing countries that used inexpensive DDT extensively to control malaria and other pests faced a significant dilemma. Moreover, although the United States no longer used DDT, it continued to manufacture and export very large quantities to developing countries and how much DDT is still used. It is difficult to say with accuracy exactly which countries still use DDT. Some countries use it illegally, others only in small quantities. And information is often impossible to obtain because questionnaires from an organization like the World Health Organization (WHO) generally have only a 50 to 60 percent response rate. Nonetheless, it is known that poorer countries in Central and South America, Africa, and Asia, as well as the large nation of China, continue to utilize sizable quantities of DDT. SEE ALSO BIOACCUMULATION; CARSON, RACHEL; FEDERAL INSECTICIDE, RODENTICIDE AND FUNGICIDE ACT; INTEGRATED PEST MANAGEMENT; PERSISTENT ORGANIC POLLUTANTS (POPS); PESTICIDES.

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Clive A. Edwards

Dense Nonaqueous Phase Liquid (DNAPL)

See Nonaqueous Phase Liquids.

Detergents

See Water Pollution: Freshwater

Dichlorodiphenyl trichloroethane

See DDT

Diesel

Rudolf Christian Karl Diesel (1858–1913), a German thermal engineer, invented the diesel engine and patented it in 1893. Unlike their gasoline counterparts, which ignite an air/fuel mixture using spark plugs, diesel engines compress air to a very high pressure and then inject the fuel. The fuel then ignites due to the high temperature of the compressed air. Diesel engines are relatively fuel-efficient engines commonly used in heavy construction equipment, ships, locomotives, commercial trucks, and some large pickups, as well as in the production of electricity at some power plants or in factories.

Diesel-powered automobiles gained popularity in the United States during the oil crisis of the 1970s because they tend to result in better fuel economy than their gasoline counterparts. But diesel-powered cars have declined in popularity with American drivers since their peak in the mid-1970s because of quality-related problems in early models and because earlier diesel engines did not accelerate as quickly as those powered by gasoline. Diesel passenger cars have also declined in popularity because they are more expensive and they emit more smog-forming pollutants and toxic soot than other conventional internal-combustion engines. For eighteen-wheel trucks and other large vehicles, however, diesel engines are currently the standard. SEE ALSO VEHICULAR POLLUTION.

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David Friedman

Dilution

Dilution was the solution to pollution when populations were small. Everything people wanted to get rid of went into the water. These wastes were typically organic, such as human wastes and animal carcasses. They became food for animals, macroinvertebrates, bacteria, and fungi that broke down the waste. As small villages grew into towns and towns into cities, waterways were overwhelmed by the amount of disposed wastes, and many rivers became open sewers.

A larger problem developed during the Industrial Revolution. Chemicals used in industry were added to the mix in the rivers. Many of these substances could not be broken down naturally or biodegraded even in wastewater treatment plants. But because lower concentrations of cancer-causing pollutants, for instance, proved less harmful or had no effect in animal studies, the dilution of pollutants in large amounts of water was thought to be an effective method of disposal. Scientists, however, have recently discovered that many pollutants (pesticides, industrial chemicals, and pharmaceuticals) mimic hormones and can interfere with the reproduction of birds and fish at parts per million (ppm) to parts per billion (ppb). Dilution cannot render these pollutants harmless.

Nor does dilution work for chemicals that bioaccumulate. These persist through the food chain and increase in each organism. The U.S. Environmental Protection Agency (EPA) has banned twenty-two bioaccumulating chemicals (BCCs) in its Great Lakes Initiative (1995), including dichlorodiphenyl trichloroethane (DDT), polychlorinated biphenyls (PCBs), mercury, and dioxins. The Great Lakes Basin 2020 Action Plan of Environment Canada's Great Lakes Programs is working on the same problems. The International Joint Commission has designated forty-two areas of concern (AOCs) or pollution hot spots in the Great Lakes region. EPA regulations require industries using these chemicals to treat them at the source rather than releasing them into waters.

The Whole Effluent Toxicity (WET) test is used to test the toxicity of effluent flowing into uncontaminated waters. The WET test is species-specific. The EPA has developed "Self-Implementing Alternate Dilution Water Guidance." This is included in any National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA and would be used if a WET test shows the toxicity of water at the site for the species specified by the NPDES permit. SEE ALSO BIOACCUMULATION; BIOREMEDIATION; MIXING ZONE; WATER POLLUTION.

Diana Strnisa

Dioxin

Dioxin, formed by burning chlorine-based chemical compounds with hydrocarbons, is one of the most toxic chemicals known. *Dioxin* is a general term

GENERAL FORMULAS OF POLYCHLORINATED DIBENZODIOXINS (PCDD) AND POLYCHLORINATED DIBENZOFURANS (PCDF)

PCDD PCDF

defoliant an herbicide that removes leaves from trees and growing plants

congener a member of a class of chemicals having a of similar structure

antimicrobial an agent that kills microbes

that describes a group of hundreds of chemicals that are highly persistent in the environment. It was the highly toxic impurity of Agent Orange, a **defoliant** used during the Vietnam War, and was the basis for evacuations in Times Beach, Missouri, and Seveso, Italy.

Dioxin has become the synonym for polychlorinated dibenzo[1,4]dioxins (PCDD) in general or the most toxic **congener** 2,3,7,8-tetrachloro dibenzo[1,4]dioxin (TCDD) in particular. PCDD comprise a group of seventy-five structurally similar compounds, so-called congeners. The individual congeners differ in the number and positions of the chlorine atoms in the molecule. Structurally related are the polychlorinated dibenzofurans (PCDF) (135 congeners). PCDD and PCDF are stable and fat-soluble molecules classified as persistent organic pollutants (POPs). The central element of the PCDD is the dioxin 6-ring, containing two oxygen atoms, while in PCDF it is the furan 5-ring, containing one oxygen atom. Apart from the structural similarity, they are often formed in the same processes, such as combustion.

PCDD and PCDF are formed incidentally in combustion and chemical production processes. Combustion processes include municipal and backyard waste incineration, residential and industrial burning of wood and coal, internal combustion in vehicle engines, and forest fires. Prerequisites for PCDD and PCDF formation are the presence of carbon compounds and inorganic or organic chlorine sources (e.g., sodium chloride or polyvinyl chloride). Their creation generally requires temperatures around 300°C and an excess or lack of oxygen. PCDD and PCDF are present as impurities in a variety of chemical products.

Chlorophenol-based pesticides like 2,4,5-T, a phenoxy herbicide, were responsible for up to half the environmental emissions of PCDD and PCDF in the early 1970s. A 1:1 mixture of 2,4-D and 2,4,5-T was used in Agent Orange; it contained elevated levels of PCDD. An estimated 110 to 170 kilograms (kg) of 2,3,7,8-TCDD alone were sprayed with herbicides over Vietnam. Consequently, acute and chronic health effects were observed in the exposed population and military personnel. Further examples of PCDD-contaminated chemical products are the wood, leather, and textile preservative pentachlorophenol, the widely used **antimicrobial** triclosan, and PCDF in polychlorinated biphenyls (PCBs). Certain thermal metallurgical processes as well as chlorine-based pulp and paper bleaching emit PCDD and PCDF into the environment. In its 1995 inventory, the U.S. Environmental Protection Agency (EPA) identified municipal and medical waste incineration, backyard refuse barrel burning, secondary copper smelting, and cement kilns burning hazardous waste as the largest current sources of dioxin-like compounds.

Mentally handicapped Vietnamese children and teenagers, suffering from the harmful effects of Agent Orange. (AP/Wide World Photos. Reproduced by permission.)

It has been claimed that 2,3,7,8-TCDD is the most toxic human-made compound, an ultra-poison. Although some evidence supports this view, the results of many studies are still controversial. 2,3,7,8-TCDD is extremely toxic to guinea pigs (the lethal dose is approximately 1 microgram or μg). For other animals and apparently for humans the acute toxicity is considerably lower. Long-term effects appear to be more serious. 2,3,7,8-TCDD was found to be the most potent **multisite** carcinogen in test animals, and PCDD and PCDF are also a human carcinogen. Noncancer effects may pose an even greater threat to human health. These include effects on reproduction and sexual development, **teratogenic** effects, endocrine disruption, suppression of the immune system, and neurological effects. PCDD and PCDF bioaccumulate and are stored in the body fat of higher organisms. About 95 percent of human exposure originates from food, especially fish, meat, eggs, and dairy products.

multisite several sites

teratogenic causing birth defects

A 1990 global emission inventory estimated that municipal waste incineration was the major source of PCDD and PCDF in the environment. Abatement strategies focus on this issue. State-of-the-art incinerators may act as sinks for dioxins, but they are expensive to construct and operate. At a higher cost-efficiency, PCDD and PCDF reduction could be achieved by a reduction in the amount of garbage to be destroyed (e.g., by manufacturing long-lived products and using less packaging), a cessation of open waste

burning, and technical improvements in as of yet less strictly regulated facilities such as cement kilns and metallurgical industries.

The remediation of dioxin-contaminated sites requires sophisticated abatement methods. Cleaning the Times Beach Superfund site was a ten-year effort that included the relocation of its inhabitants, construction of a series of spur levees surrounding the site to prevent floodwater from carrying contaminated soil off-site, installing a temporary incinerator, and the excavation and burning of 265,000 tons of contaminated soil. SEE ALSO Burn Barrels; Cancer; Endocrine Disruption; Health, Human; Incineration; Medical Waste; Persistent Organic Pollutants (POPs); Superfund; Times Beach, Missouri; War.

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Stefan Weigel

Dirty Dozen *See Persistent Organic Pollutants (POPs)*

Disasters: Chemical Accidents and Spills

By their nature, the manufacture, storage, and transport of chemicals are accidents waiting to happen. Chemicals can be corrosive, toxic, and they may react, often explosively. The impacts of chemical accidents can be deadly, for both human beings and the environment.

Many if not most products we use in everyday life are made from chemicals and thousands of chemicals are used by manufacturing industries to make these products. The source of many of these chemicals is petroleum, which is refined into two main fractions: fuels and the chemical feedstocks that are the building blocks of plastics, paints, dyes, inks, polyester, and many of the products we buy and use every day. Fuels and chemical feedstocks made from petroleum are called organic chemicals. The other important class of chemicals is inorganics, which include acids, caustics, cyanide, and metals. Commercial products made from inorganics range from car bodies to computer circuit boards.

Of the more than forty thousand chemicals in commercial use, most are subject to accidental spills or releases. Chemical spills and accidents range from small to large and can occur anywhere chemicals are found, from oil drilling rigs to factories, tanker trucks to fifty-five-gallon drums and all the way to the local dry cleaner or your garden tool shed.

A train derailment near Milligan, Florida. The train carried chemicals, which were spilled at the site. (©Bettmann/Corbis. Reproduced by permission.)

One of the worst industrial chemical disasters occurred without warning early on the morning of December 3, 1984, at Union Carbide's pesticide plant in Bhopal, India. While most people slept, a leak, caused by a series of mechanical and human failures, released a cloud of lethal methyl isocyanate over the sleeping city. Some two thousand people died immediately and another eight thousand died later. Health officials, not informed about chemicals at the factory, were completely unprepared for the tragedy.

Congressional hearings that followed the Bhopal accident revealed that U.S. companies routinely discharged hazardous chemicals into the air, while emergency planners knew little about the potential for disaster at local industrial facilities. Less than a year later, a Union Carbide plant that produced methyl isocyanate in Institute, West Virginia, leaked a toxic cloud in the Kanawha Valley. While the West Virginia incident was not another tragedy, it was a shocking reminder that an accident such as the one that occurred at Bhopal could happen in the United States.

The hearings and media attention to institute led to enactment of the Emergency Planning and Community Right to Know Act of 1986 (EPCRA), requiring companies to provide information about their potentially toxic chemicals. At the same time, states were required to establish emergency planning districts and local committees to prepare for any emergency—a fire, an explosion, a flood that might result in the release of chemicals into the environment. In 2003, more than 31,000 industrial facilities must report

more than 650 individually listed toxic chemicals and chemical categories to the U.S. Environmental Protection Agency (EPA) that is made public in the Toxic Release Inventory.

In 1990, amendments to the Clean Air Act required industrial chemical companies to submit a risk management plan that included "worst case" chemical accident scenarios. Industry leaders did not want these potential disasters made public and argued that they could alert terrorists which facilities to target. In July 2002, the Senate's Environment and Public Works Committee approved a bill to identify plants vulnerable to terrorist attacks that produce hazardous chemicals. Congress also voted against a landmark community right to know law that would have required some 6,600 chemical facilities to reveal their "worst case" accident scenarios.

Although the major chemical accidents seem most threatening because they often kill people outright, it is the smaller, more routine accidents and spills that affect most people. Some of the most common spills involve tanker trucks and railroad tankers containing gasoline, chlorine, acid, or other industrial chemicals. Many spills occur during the transportation of hazardous materials; one study found that 18,000 hazardous materials spills occurred during 1976. In 1983, spills from 4,829 highway and 851 railroad accidents resulted in eight deaths, 191 injuries, and damages exceeding more than $110,000,000. The National Environmental Law Center reported that 34,500 accidents involving toxic chemicals were reported to the EPA's Emergency Response and Notification System between 1988 and 1992, meaning that on average, a toxic chemical accident was reported nineteen times a day in the United States, or nearly once every hour.

Emergency response workers are especially at risk. In 1988 six firemen were killed minutes after arriving at the scene of two burning pick-up trucks in Missouri, when more than 30,000 pounds of ammonium nitrate stored in a nearby trailer exploded. This incident led to the formation of the hazardous materials division of the Kansas City, Missouri, Fire Department, specializing in hazardous materials handling.

To help emergency responders know what they are dealing with, the Department of Transportation (DOT) has established a hazardous materials placard system. Rail cars and trucks carrying toxic or dangerous materials must display a diamond-shaped sign having on it a material identification number, which can be looked up to determine what hazardous materials are on board, and a hazard class number and symbol that tells whether the contents are flammable, explosive, corrosive, etc. Color codes also convey instant information: blue (health), red (flammability), yellow (reactivity), white (special notice). The placard system is as follows:

Hazard class 1: Explosives (class 1.1-1.6, compatibility groups A–L)

Hazard class 2: Gases (nonflammable, flammable, toxic gas, oxygen, inhalation hazard)

Hazard class 3: Flammable liquids

Hazard class 4: Flammable solids (flammable solid, spontaneously combustible, dangerous when wet)

Hazard class 5: Oxidizer and organic peroxide

This boy is looking at a Greenpeace poster, which expresses solidarity for the victims of the Union Carbide chemical disaster in Bhopal, India, eighteen years after the incident. (Photograph by Indranil Mukherjee. © AFP/Corbis. Reproduced by permission.)

Hazard class 6: Toxic/poisonous and infectious substances labels (PG III, inhalation hazard, poison, toxic)

Hazard class 7: Radioactive (I, II, III, and fissile)

Hazard class 8: Corrosive

Hazard class 9: Miscellaneous dangerous goods

One of the most common concerns over chemical accidents and hazardous materials spills is acute, or short-term, toxicity. Acutely toxic contaminants, such as cyanide and chlorine released from hazardous materials spills, pose an immediate threat to public health. For example, a chemical accident in which chlorine gas or cyanide gas is released would likely result in widespread deaths as the plume, or toxic cloud, moved through a populated area. Another class of toxicity is chronic, or long term. One of the most common types of chronic toxicity is exposure to **carcinogens** that may result in cancer twenty to thirty years after the time of the spill. An example of such an exposure occurred on July 10, 1976, in Meda, Italy, a small town about 12 miles north of Milan, where an explosion occurred at the ICMESA chemical plant in a 2,4,5-trichlorophenol reactor. (2,4,5-Trichlorophenol is an industrial chemical used as a building block to make pesticides and antiseptics.) A toxic cloud containing dioxins, which are very potent cancer-causing chemicals, was released into the atmosphere and spread across the nearby densely populated city of Seveso. Exposure to such carcinogens does not result in short-term health problems, but the effects may be expressed decades later. An investigation of women who were exposed to high levels of dioxin in the ICMESA explosion was published in 2002. The researchers found that the women who developed breast cancer had a ten-fold increase of the toxic chemical in their blood.

carcinogen any substance that can cause or aggravate cancer

Another very different effect of chemical spills and accidents is ecotoxicity, a toxic effect on the environment rather than on human health. The most dramatic ecotoxicity resulting from chemical spills results from petroleum spills at sea or in rivers or lakes. When such a catastrophe occurs, the toxicity often depends on the type of petroleum. The most common material spill,

crude oil, contains some toxic chemicals that dissolve in the water. Most of the petroleum, however, floats on the water's surface. It causes environmental damage by coating the feathers of birds and the gills of fish, physically disrupting their movements and their ability to breathe. Oil washed ashore also disrupts marine life in fragile areas. One of the worst oil spill disasters in history occurred on March 24, 1989, when the oceangoing oil tanker *Exxon Valdez* ran aground on Bligh Reef in Alaska's Prince William Sound. Nearly eleven million gallons of crude oil spilled from the ship, and every **trophic** level of the biologically rich waters of Prince William Sound was severely impacted. Some residual oil remains to this day.

trophic related to feeding

How Are Chemical Accidents Handled?

Emergency response personnel are involved in assessing the risk of hazardous material releases and working to avoid any harmful effects. Teams of workers evaluate the concentrations of the chemicals, where and how people might be exposed, and potential toxic effects on the exposed people. In many cases, emergency response teams are on twenty-four-hour call; if a spill occurs, they use source data (such as the hazmat placards on trucks and tanker cars), databases of chemical properties, and chemical movement models to rapidly predict the movement of contaminants and the toxicity of the spilled chemicals. If rapid spill cleanup is necessary, the emergency response team designs and implements cleanup measures to protect exposed populations and ecosystems from toxic responses. A wide range of cleanup systems has been developed for chemical spills. Small spills on land are cleaned up by simply excavating the contaminated soil and moving it to a secure landfill. Oil spills on water are contained using floating booms and adsorbents, or solid materials that capture the soil, so that it can be disposed of in landfills. Newer, more innovative methods for spill cleanup include bioremediation (using bacteria to metabolize the contaminants) and chemical oxidation (using oxidants, such as hydrogen peroxide and ozone to break the chemicals down). Although chemical spills represent potentially very large environmental problems from a wide range of chemicals, emergency response procedures developed by environmental scientists and engineers are providing solutions to the resulting human health and ecological effects.

Chemical accidents and spills can be devastating to humans, wildlife, and the environment. The best way to reduce the harm caused by chemical accidents is to design plants with better safety controls that operate at lower temperatures and pressures, and to use and manufacture less toxic compounds, a field that is being pursued by "green" chemists and engineers. But until toxic chemicals are routinely replaced by less harmful substitutes, the emergency response procedures developed by environmental scientists and engineers help lessen the human health and ecological effects of chemical spills and accidents.

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Richard J. Watts and Patricia Hemminger

Disasters: Environmental Mining Accidents

Some of the most publicized environmental disasters are associated with the mining industry. These disasters are attributed to both natural and mining-related causes. Acid drainage, for example, formed by rainwater or snowmelt in contact with mineral deposits can damage nearby **ecosystems** by polluting streams and destroying wildlife. The mining and processing of ores, however, may accentuate and accelerate the natural processes.

ecosystem the interacting system of a biological community and its nonliving environmental surroundings

Long- and Short-term Impacts of Mining in the Environment

On a long-term basis, mining can increase the acidity of water in streams; cause increased sediment loads, some of which may be metal-laden, in drainage basins; initiate dust with windborne pathogens; and cause the release of toxic chemicals, some contained in exposed ore bodies and waste rock piles and some derived from ore-processing reactions. Contaminants containing such toxic chemicals as cyanide and lead may be transported far from a mining site by water or wind, polluting soils, groundwater, rivers, and the atmosphere. These toxic chemicals can be remobilized intermittently (e.g., by intense wind or rainstorms) and eventually distributed over vast regions. Some of this contamination, because of its scale or intensity, may not be amenable to **remediation**.

remediation cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site or for the Asbestos Hazard Emergency Response program

topography the physical features of a surface area including relative elevations and the position of natural and man-made (anthropogenic) features

Mining may also have effects that can be short-term, depending on their severity, such as distortion to the surrounding **topography** or removal of vegetation. In many cases, these effects may be minimized or even prevented by means of a comprehensive mining plan that includes a reclamation and remediation stage. For example, in 1999 the Ruby Hill Mine, an open-pit gold mine located near Eureka, Nevada, received an "Excellence in Mine Reclamation Award," which is granted jointly by various state and federal mining and environmental bodies. Since its inception, the mine has exhibited outstanding innovation in its design, mitigation, and reclamation, all of which is the basis of the award. One of the techniques employed by the mine is concurrent reclamation practice. Since initial exploration, disturbed areas are continuously relegated to facilitate erosion control and provide improved esthetical value. In addition, one mitigation measure that was cited is the effort to offset potential impacts to local wildlife by constructing nesting structures for bats and hawks. As of 2002, the mine was still in operation.

Case Studies

The Summitville Mine in Colorado has become a case study of environmental damage as a result of mining. Gold was mined there from 1870 until 1992. In 1994 the U.S. Environmental Protection Agency (EPA) declared the area a Superfund site. Some of the following events affected the environment at the mine: Geologic characteristics at the mine site contributed to the generation of both natural and mining-related acid drainage; the height of the containing

leach solution in mining: chemical solution sprayed on ore to extract metal

French drain buried plastic tubing with numerous holes, to collect or disperse water

leach pad in mining: a specially prepared area where mineral ore (especially gold) is heaped for metal extraction

watershed the land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds

hydrology the science dealing with the properties, distribution, and circulation of water

dike for cyanide **leach solutions** (used to chemically extract gold) was below the level required for snowstorms and spring runoff; broken pump lines and a **French drain** beneath the **leach pad** caused cyanide-contaminated solutions to be released into the local **watershed**; several waste rock piles at the mine reacted with rain and snowmelt to form acidic waters that flowed into area streams; an underground tunnel released large volumes of contaminated waters; and mining deforested much of the land. Remediation of the site has included such projects as backfilling mine waste into existing open pits, which reduces polluted water percolating into the ground; plugging underground tunnels; and replanting. Remediation is ongoing with the goal of restoring the nearby Alamosa River to support aquatic life; the U.S. Public Health Service classified this site as "no apparent public health hazard."

Another case study is the Iron Mountain Mine in California, which the EPA declared a Superfund site in 1983. Mining for copper, gold, silver, and zinc began in 1879 and continued until 1963 using underground and open-pit methods. The site contains inactive mines and numerous waste piles from which harmful quantities of untreated acidic, metal-rich waters were discharged. Mining operations fractured the mountain, changing the **hydrology** and exposing the mineral deposit to oxygen and water, which resulted in intense acid mine drainage into nearby creeks and waterways. These caused numerous fish kills and posed a health risk to the area drinking water. Some current remediation projects include: capping areas of the mine and the diversion of nearby creeks, both of which serve to reduce surface water contamination; construction of a retention reservoir to control the area source acid mine drainage discharges; enlargement of a landfill to provide an additional thirty years of storage capacity for heavy metals sludges; and construction of a significant upgrade to facilities in mine tunnels to assure safe travel for workers and equipment to perform maintenance and routinely remove mine wastes from the tunnels and other projects. SEE ALSO ACID RAIN; HEAVY METALS; MINING; SUPERFUND; WATER POLLUTION.

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Michael J. McKinley

Disasters: Natural

A natural disaster can be defined as some impact of an extreme natural event on the ecosystem and environment, and on human activities and society. The concept relies on the interaction of a natural agent—the hazard—with human vulnerability to produce a risk that is likely to eventually materialize as a destructive impact.

Lava flow from an eruption of Mount Etna, Sicily, destroys all trees and plants in its path. (©Vittoriano Rastelli/Corbis. Reproduced by permission.)

Understanding Hazards and Disasters

The driving force, or trigger, of disaster is the natural agent. In this context natural disasters are distinguished—earthquakes, floods, hurricanes, landslides, volcanic eruptions, and so on—from technological ones (toxic spills, transportation accidents, explosions in industrial plants, etc.) and social disasters (riots, acts of terrorism, crowd crushes, etc.). Experts on natural disaster tend to confine the definition to extreme geophysical phenomena and not include disease **epidemics** and the corresponding afflictions in animals (epizootics) and plants (epiphytotics), although phenomena such as locust infestations are sometimes considered. Epidemics are excluded mainly in order to narrow the field to manageable levels, rather than as the result of any theoretical justification. Indeed, students of disaster increasingly prefer not to distinguish between the three categories, which overlap considerably in terms of their effects, if not their generating mechanisms.

epidemic rapid spread of disease throughout a population, or a disease that spreads in this manner

Hazard, the catalyst for natural disaster, is subject to rules of magnitude and frequency. Generally, small events tend to be relatively frequent and large ones infrequent. In this context, considerable problems arise in preparing for large volcanic eruptions, as the timescale on which they may occur (e.g., once every 10,000 years) can be very different from that of human organization (months and years). In their more benign, everyday forms, many natural hazards can be considered as resources. Water, for instance, is a life-sustaining resource unless it comes in excessively large or small quantities, giving rise to flood or drought, respectively.

The greatest known natural disaster occurred some 65 million years ago when a mountain-sized comet or asteroid slammed into the earth near what is now Mexico's Yucatan peninsula. Scientists are boring a one-mile deep hole into the Chicxulub crater to learn more about the catastrophic event. By 2002, they had reached the top of the breccia layer at 2,800 feet down, bringing up a core of smashed rock-rubble. The devastation caused by the collision so drastically disrupted the earth's ecology that it brought about the extinction of dinosaurs and opened the way for the age of mammals.

The variation of flood hazards from very abrupt flash floods to much more slowly rising inundations, caused, for instance, when rivers swell from the gradual melting of snow, illustrates that hazards can strike along a continuum, from instantaneous impact to the gradual or long drawn-out effects of the so-called creeping disasters. The **archetypal** sudden-impact disaster is the earthquake, which usually strikes without warning and causes its worst effects within a minute or two of inception. At the other end of the continuum, one might regard accelerated soil erosion and **desertification** as creeping disasters, which may take years or centuries to reach catastrophic levels.

archetype original or ideal example or model

desertification transition of arable land to desert

disaster cycle phases in the public response to a disaster: preparedness, disaster, response, recovery, and mitigation of effects

Magnitude alone does not govern the hazardousness of an extreme natural phenomenon. Consider, for example, the Sherman landslide that occurred in central Alaska in 1964. About 29 million cubic meters of rock debris traveled more than five kilometers at an estimated maximum speed of 180 kilometers per hour. However, as the event took place in an uninhabited area and had no real human consequences, it was a mere geological curiosity, not a disaster. In contrast, the landslide of October 21, 1966, at Aberfan, South Wales, involved one-hundredth as much debris traveling one-twelfth of the distance at one-twentieth of the speed, but it demolished two schools and an area of housing, resulting in 144 deaths, 116 of them schoolchildren. It was thus a very significant disaster. This illustrates that human vulnerability is a fundamental determinant of disaster potential.

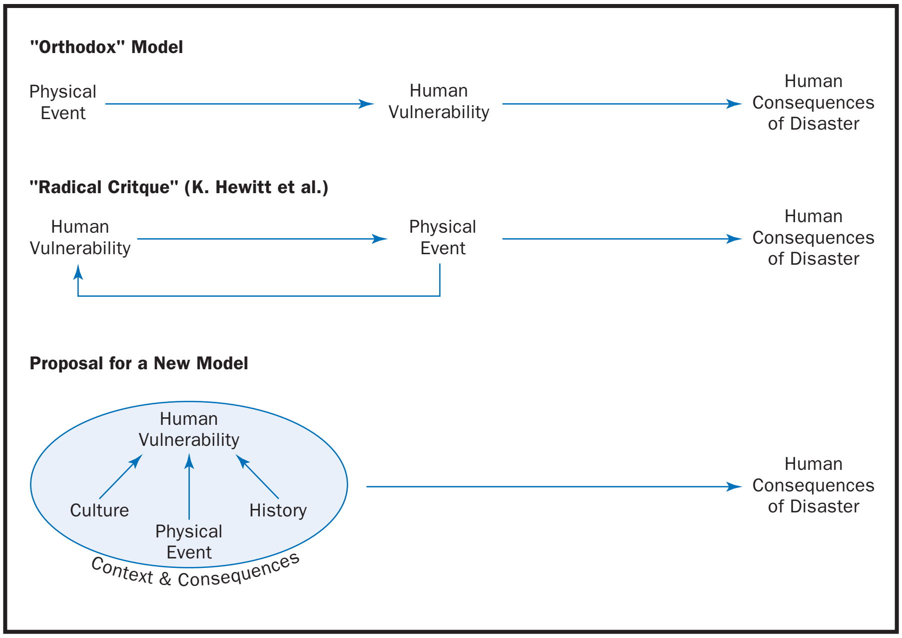
Natural catastrophe has often been studied using as a basic model the **disaster cycle**, which emphasizes the common repetitiveness of disasters. Five phases are distinguished: (1) *mitigation*, a period of inactivity in which there is time to reduce the risks of disaster; (2) *preparation*, in which hazard monitoring and forecasts show the need to prepare for an impending event; (3) *impact and emergency response*, the short-term aftermath in which basic needs such as food, shelter, and public safety must be met; (4) *restoration and recovery*, in which basic services are restored; and (5) *reconstruction*, in which the damage is repaired, perhaps over an extended period of time, a decade or more if the catastrophe was significant enough. Each phase has its own set of requirements and, in a well-organized society, programmed responses.

Trends in Losses and Casualties

The worldwide picture of disasters shows that death tolls are fairly stable, although not significantly decreasing, but losses are rising steeply. Social, economic, and military instability coupled with high rates of population growth fuel increases in the casualties and hardship caused by natural disasters in developing countries. Since the early 1990s much attention has been focused on the **complex emergency**, in which persistent warfare, particularly of the low-intensity guerrilla kind, leads to social and economic breakdown, which then interacts with repeated natural disasters, especially flood and drought. Much of the complexity of the resulting situation lies in trying to end the conflict while reinstating sustainable development and disaster efforts, or at least avoiding political and military control of relief supplies, with all the ensuing moral dilemmas that aid agencies must face in order to maintain their neutrality.

complex emergency a humanitarian crisis in which there is a breakdown of political authority

In richer countries death tolls in natural disaster tend to be low (e.g., an average of 570 a year in the United States), but the cost of damage and other losses has skyrocketed. The 1989 Loma Prieta, California, earthquake caused



approximately $12 billion in losses. The 1994 Northridge earthquake, also in California, resulted in costs more than twice that amount, but a year later the Hanshin-Awaji earthquake in Kobe, Japan, cost an estimated $131.5 billion. The scenario for a future repeat of the 1923 Tokyo earthquake points to losses of $2,800 billion. In part, however, this reflects a growing tendency to quantify new forms of indirect impact, especially lost production and sales. Nevertheless, the losses are undeniably rising, which points to growing economic vulnerability to disasters. Although in percentage terms insurance payments after disasters have doubled since the early 1990s, they still only cover one-sixth of losses, and the insurance industry is struggling to find the capital to underwrite huge claims: In 1992 Hurricane Andrew sent eight insurance companies in Florida into receivership.

The Future of Disaster Preparedness

As losses increase and casualties remain frequent and widespread, the problem of natural catastrophes is topical and pressing. Expertise is gradually accumulating on how to best tackle disaster, and new agencies for managing it are forming at the local, regional, national, and international levels. For such efforts to succeed, rigorous standards need to be established for emergency planning, management, and training. There needs to be more investment in both structural and nonstructural mitigation: As it is based on organization rather than civil engineering, the latter is often more cost-effective than the former. From the point of view of understanding disaster as a phenomenon, more attention needs to be given to the role of context and culture in perceiving and interpreting the needs generated by hazards and disaster impacts. SEE ALSO Economics.

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David E. Alexander

Disasters: Nuclear Accidents

Of all the environmental disaster events that humans are capable of causing, nuclear disasters have the greatest damage potential. The radiation release associated with a nuclear disaster poses significant **acute** and **chronic** risks in the immediate environs and chronic risk over a wide geographic area. Radioactive contamination, which typically becomes airborne, is long-lived, with **half-lives** guaranteeing contamination for hundreds of years.

acute in medicine, short-term or happening quickly

chronic in medicine, long-term or happening over time

half-life the time required for a pollutant to lose one-half of its original concentration; for example, the biochemical half-life of DDT in the environment is fifteen years

Concerns over potential nuclear disasters center on nuclear reactors, typically those used to generate electric power. Other concerns involve the transport of nuclear waste and the temporary storage of **spent radioactive fuel** at nuclear power plants. The fear that terrorists would target a radiation source or create a "dirty bomb" capable of dispersing radiation over a populated area was added to these concerns following the 2001 terrorist attacks on New York City and Washington, D.C.

spent radioactive fuel radioactive fuel rods after they has been used for power generation

Radioactive emissions of particular concern include strontium-90 and cesium-137, both having thirty-year-plus half-lives, and iodine-131, having a short half-life of eight days but known to cause thyroid cancer. In addition to being highly radioactive, cesium-137 is mistaken for potassium by living organisms. This means that it is passed on up the food chain and **bioaccumulated** by that process. Strontium-90 mimics the properties of calcium and is deposited in bones where it may either cause cancer or damage bone marrow cells.

bioaccumulation buildup of a chemical within a food chain when a predator consumes prey containing that chemical

Fears of terrorist attacks on nuclear power plants have prompted state and local health offices to distribute supplies of potassium iodide pills, known as KI, to be taken in the event of a release of radioactive materials. KI blocks the intake of radioactive iodine by the thyroid and helps prevent thyroid cancer. The pills were provided by the Nuclear Regulatory Commission.

The Chernobyl Disaster

Concern became reality at 1:23 A.M. on April 25, 1986, when the worst civil nuclear catastrophe in history occurred at the nuclear power plant at Chernobyl, Soviet Union (which is now in Ukraine). More than thirty people were killed immediately. The radiation release was thirty to forty times that of the atomic bombs dropped on Japan during World War II. Hundreds of thousands of people were ultimately evacuated from the most heavily contaminated zone surrounding Chernobyl. Radiation spread to encompass almost all of Europe and Asia Minor; the world first learned of the disaster when a nuclear facility in Sweden recorded abnormal radiation levels.

Chernobyl had four RBMK-type reactors. These reactors suffer from instability at low power and are susceptible to rapid, difficult-to-control power increases. The accident occurred as workers were testing reactor

number four. The test was being conducted improperly; as few as six **control rods** were in place despite orders stating that a minimum of thirty rods were necessary to maintain control, and the reactor's emergency cooling system had been shut down as part of the test. An operator error caused the reactor's power to drop below specified levels, setting off a catastrophic power surge that caused fuel rods to rupture, triggering explosions that first destroyed the reactor core and then blew apart the reactors' massive steel and concrete containment structure.

control rod a rod containing substance that absorbs neutrons inserted into a nuclear reactor to control the rate of the reaction

The health impacts of the Chernobyl explosion will never be fully known. It is estimated that some three million people still live in contaminated areas and almost ten thousand people still live in Chernobyl itself. The plant itself was not fully shut down until nearly fifteen years after the disaster. Studies by the Belarus Ministry of Health, located approximately eighty miles south of Chernobyl, found that rates of thyroid cancer began to soar in contaminated regions in 1990, four years after the radiation release. Gomel, Belarus, the most highly contaminated region studied, reported thirty-eight cases in 1991. Gomel normally recorded only one to two cases per year. Health officials in Turkey, 930 miles to the south, reported that leukemia rates are twelve times higher than before the Chenobyl accident.

Three Mile Island

The thriller *China Syndrome*, which warned that a nuclear power plant meltdown would blow a hole through the earth all the way to China and "render an area the size of Pennsylvania permanently uninhabitable" had been playing for eleven days when, at 4:00 am on March 28, 1979, Reactor #2 at the Three Mile Island (TMI) nuclear power plant suffered a partial meltdown. The plant was just downriver from Harrisburg, Pennsylvania.

Film story, reality, and perception all interplayed to create near national panic. The accident occurred sequentially. A minor problem caused the temperature of the primary coolant to rise. In one second, the reactor shut down but a relief valve that was supposed to close after ten seconds remained open. Plant instrumentation showed operators that a "close valve" signal had been sent. There was no instrumentation to tell them the valve itself was still open. The reactor's primary coolant drained away and the reactor core suffered serious damage. Fuel rods were damaged, leaking radioactive material into the cooling water and a high temperature chemical reaction created bubbles of hydrogen gas. One of these bubbles burned, creating fears that a larger hydrogen bubble would explode, possibly breaching the plant's containment structure. Some gases were purposefully vented into the atmosphere.

It took nearly a full month the bring the reactor into "cold shutdown" status. That said, there was never danger of a massive explosion and hundreds of readings taken by the Pennsylvania Department of Environmental Resources showed almost no iodine, and all readings were far below health limits. There was, however, widespread panic including a unordered mass evacuation. The greatest problem at TMI was a total failure of communication. Internal radioactivity levels, for example, were reported as ambient (outdoor) air readings.

The many health studies following TMI showed no evidence of abnormal cancer rates. For eighteen years, the Pennsylvania Department of Health maintained a registry of 30,000 people who lived within five miles of TMI; it

A civil defense worker is using Geiger counter to check radiation level near a school building following the accidental radiation leak from the nearby Three Mile Island nuclear power plant. Schoolchildren are being evacuated via bus. (©Wally McNamee/Corbis. Reproduced by permission.)

found no evidence on unusual health trends. TMI's only health effect was psychological stress related to the accident.

While there were few long-term health effects, there is no doubt that the accident at TMI permanently changed both the nuclear industry and the Nuclear Regulatory Commission (NRC). "Public fear and distrust increased," the NRC notes in a fact sheet on TMI, "Regulations and oversight became broader and more robust, and management of the plants was scrutinized more carefully."

Nuclear Submarines

On August 12, 2000, an explosion in a torpedo tube sank the giant Russian nuclear submarine *Kursk* and its crew of 118 in the Barents Sea. Russian officials described the sinking as a "catastrophe that developed at lightning

Two cooling towers at the Three Mile Island nuclear plant. (©W. Cody/Corbis. Reproduced by permission.)

speed." A week later, divers opened the rear hatch of the sub but found no survivors. It took salvagers two years, but the *Kursk* and her two nuclear reactors was raised.

The *Kursk* was the sixth nuclear submarine to have sunk since 1963. The others all came to rest on the ocean floor at depths of more than 4,500 feet, far below where most marine life lives. They include two former Soviet submarines—one that sank east of Bermuda in 1986 and another that went down in the Bay of Biscay in 1970—and two U.S. nuclear submarines—the U.S.S. *Thresher* and U.S.S. *Scorpion*—which sank in the 1960s at the height of the Cold War.

U.S. Navy officials report there is little likelihood of radioactive release from the U.S. ships. Reactor fuel elements in American submarines are made of materials that are extremely corrosion resistant, even in sea water. The protective cladding on the fuel elements corrodes only a few millionths of an inch per year, meaning the reactor core could remain submerged in sea water for centuries without releases of fission products while the radioactivity decays.

Comprehensive deep ocean radiological monitoring operations were conducted at the *Thresher* site in 1965, 1977, 1983, and again in 1986. None

of the samples obtained showed any evidence of release of radioactivity from the reactor fuel elements.

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Richard M. Stapleton

Disasters: Oil Spills

seep movement of substance (often a pollutant) from a source into surrounding areas

Liquid petroleum (crude oil and its refined products such as tar, lubricating oil, gasoline, and kerosene) can be released as catastrophic spills from point sources (e.g., from tankers and blowouts) or as chronic discharges typically from nonpoint sources (e.g., from urban runoff or fallout from the atmosphere). Releases of petroleum into the environment occur naturally from **seeps** as well as from human sources. Together natural and human sources contribute about 380 million gallons of petroleum to the oceans each year. Of this, about 45 percent comes from natural seeps, and the remainder may be attributed to the human activities of petroleum production, transportation, and consumption. Discharges during petroleum production tend to be restricted to areas of exploration and extraction and are mostly due to the release of "produced waters" (water extracted with petroleum from the reservoir); these discharges contribute about 5 percent of the petroleum reaching the sea from human sources. Spills during the transport, refinement, and distribution of petroleum are most common along shipping routes and pipelines and make up about 22 percent of human-caused petroleum inputs. Spills during petroleum consumption (i.e., use of automobiles, boats, etc.) tend to be small but are so numerous and widespread that they contribute the vast majority (about 70 percent) of human-caused petroleum pollution in the sea. Therefore, consumers could make an enormous contribution to pollution prevention through proper use of petroleum products in vehicles and other personal equipment maintained to avoid leaks and spills.

The effects of spilled petroleum on marine organisms can be lethal or sublethal. Lethal effects are often obvious after large spills, with the most attention focused on birds and mammals (e.g., 900 bald eagles, 250,000 seabirds, 2,800 sea otters, and 300 harbor seals were killed directly by the *Exxon Valdez* spill), but population-level consequences are difficult to measure. Considerable controversy arises in the determination of when populations have recovered. Even when organisms are not killed, oil fouling can reduce feeding efficiency, growth and reproductive rates, survival of offspring, and

resistance to diseases. Petroleum may act synergistically with other pollutants, such as those found in urban runoff, to cause even more toxic effects like high rates of mortality or reproductive failure. Petroleum can kill birds and mammals by reducing the capacity of feathers and fur to keep the animals warm, or through ingestion when birds and mammals attempt to remove the petroleum or eat fouled prey.

The largest oil spill in history occurred from tankers, a tank field, offshore terminals, and refineries during the 1991 Persian Gulf War; it dwarfed other spills with a release of approximately 520 million gallons of oil. This was more than three times the volume of the second-largest spill, from the IXTOC 1 blowout in the Gulf of Mexico in 1979. The 1989 spill of eleven million gallons of crude oil from the *Exxon Valdez* along 1,100 miles of Alaska's pristine southern coast was the largest spill in U.S. history and approximately the fortieth-largest spill globally. It caused a national backlash against "big oil" in the United States and led to the passage of the 1990 Oil Pollution Act. This legislation creates a cooperative arrangement between the polluter and the resource trustee in order to increase the speed and effectiveness of cleanup efforts and reduce the intensity of litigation.

Oil spills from tankers capture the most media attention, but, as of 2000, ships contributed less than 2 percent of petroleum in the oceans. This is dwarfed by the 45 percent input from natural seeps. However, seeps typically release oil at a slow constant rate and the surrounding ecosystems have adapted to the presence of oil (although species diversity is reduced), with microorganisms even using the oil as a source of energy. Tanker spills, on the other hand, often occur in ecologically sensitive near-shore areas and the volume of oil released at once can be significant. The largest human source of petroleum in the marine environment is the consumer, from sources such as personal watercraft (especially two-stroke engines), automobiles, fuel jettisoned from aircraft, and municipal waste, the sum of which aggregates into urban runoff, wastewaters, river discharge, and atmospheric deposition. These inputs are most pronounced in near-shore areas, which also have the most sensitive ecosystems (e.g., estuaries, mangrove forests, coral and oyster reefs, coastal marshes, sea grass, and kelp beds). These ecosystems derive much of their physical structure from the organisms themselves; as such, mortality due to petroleum can destroy the physical structure, leading to erosion of underlying sediments and the collapse of the ecosystem.

Current technology is insufficient to clean up large spills. Techniques in use include mechanical containment with **booms** and recovery with skimmers, suction equipment and sorbent materials, chemical treatment with dispersing and gelling agents, and physical removal via wiping, pressure washing, and raking. Scientists are developing bacterial strains to devour petroleum in spills and fertilizers to stimulate the success of these bacteria in the sea; although promising, this technique remains insufficient. A 20 percent recovery of spill volume is considered a good effort. Some cleanup efforts may do more harm than good. For example, the hot water scouring of beaches following the *Exxon Valdez* spill stripped silt from between rocks and thereby prevented recolonization by bivalves, which must wait until sediments are naturally replenished. Some of the chemical agents are toxic themselves, and a number, such as **gelling agents**, must be applied at several times the volume of the spill itself, clearly impractical for a spill of millions of gallons.

boom a floating device used to contain oil on a body of water; or, a piece of equipment used to apply pesticides from a tractor or truck

gelling agent chemical used to thicken a substance, i.e., oil, to prevent it from spreading out

Workers in orange coats standing on rocky beach using water hoses to clean up the oil spill from the *Exxon Valdez.* (Courtesy of Richard Stapleton. Reproduced by permission.)

heterotrophic phytoplankton floating microorganisms that consume other organisms for food

It is still the case that most petroleum spilled is "cleaned" by natural processes or remains for decades in the environment in forms such as tarballs accumulated on shorelines or petroleum soaked deeply into shoreline gravel. Natural cleansing of petroleum in water, particularly light oils, occurs through evaporation (10 to 75 percent during the first few days, depending on petroleum weight and environmental conditions), photooxidation, and microbial degradation by bacteria, fungi, and **heterotrophic phytoplankton**. A small amount dissolves in the water, but this increases the toxicity of the water to organisms, and petroleum suspended in water may attach to suspended sediments that eventually settle to the sea floor, from where the petroleum may be rereleased into the water.

The monetary costs of petroleum spills vary tremendously, even for identical spill volumes, depending on the sensitivity of the local ecosystem, type of petroleum released, weather, ocean currents and waves, time of year, use of local beaches, local fishing activity, presence of ecological reserves, containment and cleanup effectiveness, and many other factors. The financial responsibility for the spill lies with the polluter, but the cost of a petroleum spill is open to interpretation and often spawns litigation.

Spills from vessels in U.S. waters declined significantly during the 1990s (less than one-third of total spillage in the 1980s) due to better-designed ships (e.g., double-hull tankers and new construction materials being phased in) and more stringent regulations and operational practices. This decline in spills occurred at the same time as the global tanker fleet grew slightly to 7,270 in 1999, but by that year more than half of the fleet was less than fifteen

TEN WORST OIL SPILLS BY VOLUME, 1967–2002

Name	Location	Quantity (in millions of gallons)	Date
Arabian Gulf/Kuwait	Persian Gulf, Kuwait	380–520	January 19, 1991
IXTOC 1	Bay of Campeche, Mexico	140	June 3, 1979
Atlantic Empress	off Tobago	90	July 19, 1979
Kolva River	Kolva River tributary, Russia	84	September 8, 1994
Nowruz Oil Field	Persian Gulf, Iran	80	February 10, 1983
Castillo de Bellver	off Saldanha Bay, South Africa	79	August 6, 1983
Amoco Cadiz	Portsall, France	69	March 16, 1978
ABT Summer	off Angola	51–81	May 28, 1991
Haven	Genoa, Italy	45	April 11, 1991
Odyssey	off Nova Scotia, Canada	41	November 10, 1988
Prestige	off Spain	20	November 13, 2002

This table presents the ten largest oil spills since modern compilations began in 1967. The volumes of many major oil spills, especially those that occurred outside of North American or European waters, were not precisely measured. Where the uncertainty is large the range of possible spill volumes is given, ordered by the mid-range estimate for the spill.

years old. On the other hand, petroleum spilled from failed pipelines is projected to increase as pipelines age. North America alone has 23,000 miles of petroleum pipelines. Similarly, as the human population grows and consumes more petroleum, greater volumes of it will reach the seas from consumptive sources.

All levels of society may contribute to reductions in petroleum pollution. Governments can enact more stringent drilling, wastewater, transportation, use, and recovery regulations and more rigorously enforce them. Governments and industry can work together to ensure the integrity of the pipeline system and reduce inputs from production activities. Improvements can be made in the avoidance of spills, the tracking of vessels, including their escort by tugs, and the general safety of a tanker fleet. Government and industry can also partner to stop operational discharges such as **bilge** and fuel oil and oily **ballast**. Operational discharges are currently prohibited within fifty nautical miles of the U.S. coast, but due to noncompliance and lax regulations in many countries and international waters, these inputs are third in importance only to land-based runoff and releases from two-stroke engines. Consumers can use more efficient machinery that spills less petroleum, such as four-stroke engines for personal watercraft, and can properly dispose of petroleum products at recycling or collection centers. And society can migrate away from fossil fuels to renewable sources of energy that pose significantly fewer problems for both air and water pollution. SEE ALSO CLEANUP; PETROLEUM; UNDERGROUND STORAGE TANKS; WATER POLLUTION: MARINE.

bilge deepest part of a ship's hold

ballast material in a ship used for weight and balance

One of the most ecologically sensitive spots on earth was put at risk in January 2001 when an oil tanker ran aground and capsized on San Cristóbal Island in the Galápagos Islands. The Galápagos, described by Charles Darwin as a living laboratory of evolution, were spared when a fortuitous wind shift pushed some 170,000 gallons of diesel fuel out to sea and away from the fragile marine reserve.

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Frank A. von Hippel and Ted von Hippel

Disinfection *See Water Treatment*

Disposal *See Incineration; Injection Well; Landfill; Solid Waste*

DNAPLs *Nonaqueous Phase Liquids*

Donora, Pennsylvania

temperature inversion temporary trapping of lower warm air by higher cold air

The towns of Donora and Webster, Pennsylvania, along the Monongahela River southwest of Pittsburgh, were the site of a lethal air pollution disaster in late October 1948 that convinced members of the scientific and medical communities, as well as the public, that air pollution could kill people, as well as cause serious damage to health. The disaster took place over the course of five days, when weather conditions known as a **temperature inversion** trapped cooled coal smoke and pollution from a zinc smelter and steel mill beneath a layer of warm air over the river valley that enclosed the two towns and the surrounding farmland. Almost half of the area's 14,000 residents reported becoming ill and about two dozen deaths were attributed to the badly polluted air.

After the disaster, fact-finding studies conducted by federal, state, and local government, as well as the steel industry and private investigators, never definitively identified the exact mix of pollutants that caused the deaths and illnesses. It is believed that a thick blanket of sulfur oxides, carbon monoxide, and particulate literally smothered the towns. Donora is remembered as a key event that inspired federal air pollution legislation in the 1960s and 1970s and contributed indirectly to the establishment of the U.S. Environmental Protection Agency in 1970. It helped mobilize public sentiment in favor of federal regulation rather than continued state and local jurisdiction over polluters. SEE ALSO Air Pollution; Clean Air Act; Coal; Environmental Protection Agency; Health, Human; Heavy Metals; Industry; Laws and Regulations, United States; Smog.

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Lynne Page Snyder

Dredging

estuary region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and salt water (i.e., bays, mouths of rivers, salt marshes, and lagoons). These ecosystems shelter and feed marine life, birds, and wildlife

Dredging is the process of excavating or removing sediments from the bottom of lakes, rivers, **estuaries**, or marine (ocean) locations. Sediment excavation or dredging is conducted for multiple purposes. These purposes include navigation, mineral extraction (mining), construction activities

Noontime smog on a street in Donora, Pennsylvania, 1948. (© Pittsburgh Post-Gazette, all rights reserved. Reproduced by permission.)

(e.g., laying underwater pipeline), and the environmental cleanup of polluted sediments.

Dredging is generally conducted by floating construction equipment and is accomplished by *mechanical*, *hydraulic*, or *hydrodynamic* (agitation) processes. Mechanical dredges generally employ drag lines, open or closed clam shell buckets, or an endless chain of buckets to excavate the sediment and place it in a container such as a barge or scow. The dredged sediment is then transported in the barge or scow for beneficial use at a location on land or in the water (e.g., construction material, fill or habitat enhancement), to a nearby disposal site, or in some cases, to an aquatic disposal site at a lake, river, estuary, or ocean.

Hydraulic pipeline dredges use a suction pipe connected to an excavation device (like a huge vacuum cleaner hose with a digger at its end) for removing the dredged sediment from the bottom. In the process, the removed sediment mixes with the overlying water to form the resultant dredged material. The sediment is then pumped **hydraulically** by a pipeline to a location intended for beneficial use (e.g., beach nourishment or construction fill), to an adjacent aquatic placement location, or to an upland placement facility for storage for later beneficial or commercial uses. Contaminated sediments may be transported to off-site treatment or disposal facilities or to a contained aquatic disposal site. The nonaquatic disposal alternative for contam-

hydraulic related to fluid flow

inated sediments is much more environmentally complex when plant, animal, air (volatile), and surface and groundwater (leachate) pathways for contaminants must be controlled.

Hydraulic dredging may also be accomplished by a self-propelled ocean-going dredging vessel (e.g., hopper dredges) that will store the sediment and entrained water in a large hopper for transport to an ocean disposal site, for beneficial-use placement in the nearshore zone for beach nourishment, or for transport to a land-based containment facility. A special-purpose self-propelled hydraulic dredge known as a *side caster* excavates the sediment (e.g., entrance channel sand) and immediately pumps the material to a location adjacent to the channel, but down drift of nearshore natural prevailing currents. The currents rapidly disperse the sediments down coast, beneficially adding to the normal coastal sand movement.

Hydrodynamic dredging (agitation dredging) is a process whereby the bottom sediment is physically disturbed by mechanical (e.g., a boat's propeller) or hydraulic means (e.g., water jets). The sediment is not excavated and removed from the water body. The suspended material simply moves away from the dredging site as a result of the natural prevailing currents. The sediment never leaves the water body and is not moved or transported in a vessel or container. There is no resulting disposal or discharge from hydrodynamic (agitation) dredging.

The vast majority of dredging in the United States occurs for navigation purposes as deep channels and berths are needed for ports in lakes, rivers, estuaries and the nearshore ocean to accommodate large commercial or military vessels. These ships are an integral part of U.S. trade and also necessary for defense purposes. About 350 million tons of dredged sediments are excavated annually in U.S. waters to maintain navigation. A large percent of dredged material is clean, approximately 90 percent, and suitable for a wide variety of useful purposes, including placement back into the water at an approved aquatic disposal site. In industrial and highly urbanized areas that account for about 10 percent of the total U.S. dredging, sediments are polluted with industrial and sewage contaminants along with runoff from nearby land areas. As such, these sediments must be thoroughly tested by chemical and toxicological means and disposed of in an environmentally acceptable manner. Some aquatic areas are so heavily polluted that the sediments must be removed for cleanup from the water body and disposed of in a secure disposal facility.

Dredging for an environmental cleanup can be very controversial because of the significant expense, and the need for an environmentally suitable disposal alternative and proof that the cleanup is necessary, then effective. Environmental dredging has been used in more than thirty U.S. locations with mixed success. These sites are currently under review regarding the long-term usefulness of dredging. As a result, significant controversy (technical and political) exists as to the overall effectiveness of clean up dredging and the transfer of environmental and human health risk when huge quantities of sediment are removed from a water body and placed in an upland location. Comparative risk assessment of all practical alternatives is necessary to resolve these controversies. SEE ALSO Abatement; Bioaccumulation; Cleanup; Ocean Dumping; PCBs (Polychlorinated Biphenyls); Risk; Superfund; Water Pollution.

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Robert M. Engler

Drinking Water *See Water Treatment*

Dry Cleaning

Dry cleaning is the use of solvents instead of water to clean fabrics. It is believed to have originated in France in 1828 when a factory worker spilled lamp oil, a **flammable** petroleum-based **solvent**, on a soiled tablecloth. When the tablecloth dried, the spots had disappeared. The original solvents used in the dry cleaning industry included turpentine, kerosene, benzene, and gasoline. These are extremely flammable, often resulting in fires and explosions. Around 1900, scientists developed chlorinated hydrocarbons, which are nonflammable solvents. Initially, carbon tetra chloride was the preferred solvent, but because of its toxicity, it was eventually replaced by tetrachloroethylene, also known as perchloroethylene (PERC).

flammable any material that ignites easily and will burn rapidly

solvent substance, usually liquid, that can dissolve other substances

PERC is a colorless, clear, heavy liquid used by 90 percent of dry cleaners in the United States. Because of its significant adverse health effects, the government has imposed regulations for the control of PERC exposures and **emissions**. In addition to PERC, other compounds are used in dry cleaning, particularly during removal of stains. These include other chlorinated solvents, petroleum naptha, acetic acid, hydrogen peroxide, ammonia, and mineral spirits.

emissions substances, often polluting, discharged into the atmosphere

PERC enters the human body through both inhalation and skin exposure. Symptoms associated with overexposure include central nervous system depression, damage to liver and kidneys, and irritation of the respiratory system and skin. Those exposed may experience confusion, impaired memory, dizziness, headache, drowsiness, and eye, nose, and throat irritation. Repeated skin exposure often results in dermatitis. PERC is a known animal carcinogen and a suspected human carcinogen. The other solvents used in dry cleaning may also cause central nervous system depression and irritation of the mucous membranes, nasal passages, and skin.

The dry cleaning process begins when soiled garments are brought to dry cleaning stores. Garments with visible stains are treated at spotting

stations. Spotting chemicals, contained in squeeze bottles, are applied to the stain. The next step in the process involves washing, extracting, and drying. Clothes are manually loaded into washing machines. Detergent and solvents are poured over the garments. Water is also added to the system to aid in the removal of water-soluble soils. The contents of the machine are agitated, allowing the solution to remove the soils. Next, the clothes are spun at high speed to extract solvents. After extraction, the fabric is spun dry. Warm air vaporizes the residual solvent and unheated air is passed through to reduce wrinkles. Fresh air is added to freshen and deodorize clothing. Garments are removed and placed on the pressing machine, where they are heated to temperatures around 150°C (300°F).

filtration process for removing particulate matter from water by means of porous media such as sand or synthetic filter

distillation the act of purifying liquids through boiling, so that the steam or gaseous vapors condense to a pure liquid; pollutants and contaminants may remain in a concentrated residue

There are many steps during the dry cleaning process in which PERC and other solvents have the potential to become airborne. **Filtration** and **distillation** are the main methods used to recover solvents. Distillation removes soluble oils and greases not recovered by filtration. These processes convert PERC into a solid form that then renders it disposable as hazardous waste. The government regulates dry cleaning stores to levels of less than one hundred parts per million (ppm), but encourages them to operate at levels below twenty-five ppm. The main danger outside a dry cleaning store is to residences in the same building. Inexpensive technology, such as exhaust fans, can safely remove these potentially dangerous substances. Despite such measures, residents who live in buildings housing dry cleaning establishments, as well as workers, may be exposed to concentrations of PERC that are of public health concern.

The potential continues to exist for environmental contamination of water and soil due to improper disposal of PERC. In Katonah, New York, well water was polluted because PERC was poured down the drain in dry cleaning establishments. Proper disposal and collection of this material as a hazardous substance should be performed in order to minimize the environmental impact. SEE ALSO Air Pollution; Clean Air Act; Water Pollution.

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Iris Udasin

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Earth Day

An estimated twenty million Americans took part in the first Earth Day on April 22, 1970. Virtually every community from Maine to California hosted activities. Congress adjourned for the day. All the television networks gave it significant coverage. In New York, hundreds of thousands of people jammed Fifth Avenue from Fourteenth Street all the way to Central Park to listen to politicians, scientists, and celebrities. In San Jose, California, college students held a funeral for the internal combustion engine, and buried a new car.

An Earth flag is being held by a member of the crowd at the Capitol Building in Washington D.C., for Earth Day 1990. (© Todd A. Gipstein/Corbis. Reproduced by permission.)

Earth Day arrived at the close of the 1960s—a time of cultural and political turmoil. At its core was a growing recognition that unconstrained growth could produce a legacy of poisoned streams, filthy air, urban blight, and vanishing wilderness. Earth Day tied these issues, and a wide array of other concerns, together under the environmental banner and greatly magnified their clout and visibility. It is generally cited as marking the birth of the modern U.S. environmental movement.

Initially, some activists worried that environmental concerns might undermine other causes, such as peace and civil rights. This did not happen. Indeed, with its successful reengagement of the politically alienated middle class, Earth Day arguably helped revitalize a civil society that was becoming a bit frayed by violence at the end of the 1960s.

The roots of Earth Day can be traced to a speech given by Democratic Wisconsin Senator Gaylord Nelson at the University of Washington in September of 1969. Decrying a large oil spill in Santa Barbara as emblematic of environmental problems, he called for a **teach-in** on the environment at colleges across the country, modeled on the earlier anti–Vietnam War teach-ins.

teach-in educational forum springing from a protest movement (derived from sit-in protests)

Senator Nelson repeated variations of this speech over the next few months to enthusiastic audiences. Based on that response, he created a nonprofit organization to organize the campaign. He invited Republican Congressman Pete McCloskey to cochair the board, and asked Denis Hayes, a politically active recent graduate of Stanford University, to serve as National Coordinator.

Hayes quickly rented some ramshackle offices and assembled the core national staff. Eventually, the Washington, D.C.–based staff grew to about sixty, supplemented by a few hundred, mostly youthful volunteers. Some had been active in politics as supporters of Gene McCarthy, Robert Kennedy, or John Lindsay. Others were drawn from the **counterculture**, and were interested in recycling, organic food, solar power, and alternatives to the automobile. Under the pressure of an April 22 deadline, this diverse group put their differences aside and forged a very effective team.

counterculture collection of people whose political and social ideas stand in opposition to the mainstream culture

In early 1970 this small group of young people, most in their early twenties, made a series of decisions that were to shape and propel the environmental movement through the next few decades.

The name "Earth Day" was chosen by Hayes and his staff over beer and pizza one night for use in a full-page ad in the Sunday *New York Times.* Julian Koenig, the New York advertising executive who designed the ad for free, proposed Earth Day (his favorite) along with numerous other candidate names (Environment Day, Ecology Day, E Day) in other mockups of the ad. The ad, headlined "Earth Day: The Beginning," elicited enormous attention in the media.

Having watched other social movements of the 1960s grow exclusionary with the passage of time, Earth Day's organizers explicitly set out to engage the huge middle class that they saw as the fulcrum of American politics. They reached out to labor (organized labor was the largest source of financial support for Earth Day); K–12 education groups (NEA, AFT, and NSTA); civic and religious groups; and national associations of zoos, museums, and libraries. They took special care to cultivate strong relationships with women's groups such as the League of Women Voters, the American Association of University Women, PTAs, garden clubs, and the scouts. All were approached and urged to mobilize their huge networks of members across the country.

As the *New York Times* described the resulting campaign: "Conservatives were for it. Liberals were for it. Democrats, Republicans and independents were for it. So were the ins, the outs, the Executive and Legislative branches of government."

As the Earth Day campaign grew, an enormous range of issues emerged from the **grassroots**. These included health-damaging levels of air pollution, the misuse of pesticides (raised earlier by Rachel Carson in her landmark book, *Silent Spring*), freeways cutting through vibrant urban neighborhoods, **defoliation** resulting from the use of **mutagenic** herbicides in Vietnam, the explosive growth of the human population, the flushing of raw sewage and industrial wastes into the nation's rivers and the Great Lakes, massive clear cutting of the national forests, the environmental impacts of a proposed new **supersonic** airliner (the SST), and others. To tie all these complex issues together, Earth Day's organizers urged that the lessons of ecology—the study of the interrelationship of all creatures with their environment—be employed to create sustainable human environments.

grassroots individual people and small groups, in contrast to government

defoliation loss of vegetation

mutagenic capable of causing permanent, abnormal genetic change

supersonic faster than the speed of sound

Earth Day 1970 achieved a rare political alignment, enlisting support from republicans and democrats, rich and poor, city slickers and farmers, tycoons and labor leaders. The size and coverage of Earth Day led President Richard Nixon (who was no fan of the environmental movement, but who

expected Senator Ed Muskie, an environmental leader, to be his opponent in the 1972 election) to propose the creation of the U.S. Environmental Protection Agency (EPA).

The tough Clean Air Act of 1970 was passed with only a handful of dissenting votes in both houses of Congress. Seven of a "Dirty Dozen" congressmen—so designated by the Earth Day organizers—were defeated in the 1970 elections. The military was forced to halt the use of mutagenic defoliants in Southeast Asia. Development of the SST was halted. The Federal Occupational Health and Safety Act aimed at "in-plant pollution" was passed by a coalition of labor and environmental groups. Within the next few years, such landmarks as the Clean Water Act, the Endangered Species Act, and the Resource Conservation and Recovery Act were passed by wide margins.

Seldom, if ever, has a new issue so broadly and swiftly permeated the nation. Within a couple of years, the environment was influencing almost every aspect of American business, politics, law, education, culture, and lifestyle.

As 1990 approached, and again before 2000, environmental leaders asked Denis Hayes to organize anniversary campaigns. In 1990 Earth Day turned its attention overseas, ultimately catalyzing events in 141 countries. Earth Day 1990 gave a huge boost to recycling efforts worldwide and helped pave the way for the 1992 United Nations Earth Summit in Rio de Janeiro—the largest gathering of heads of state in history.

An estimated 200 million participants in 184 nations took part in Earth Day 2000, which included the first national environmental campaign in the history of China. Earth Day 2000 focused on global warming and low-carbon energy alternatives. It helped create worldwide political support to implement the Kyoto Protocol on climate change in 2001 over the strong opposition of the first Bush administration.

Earth Day has evolved into the first global secular holiday. Much as Americans use the occasion of Labor Day, Veterans Day, Martin Luther King Day, and other holidays to reflect on important issues, people everywhere now take time each April 22 to reflect on the health of the planet, and to ask what they can do in their jobs and their lives to improve it. A coordinating body, the Earth Day Network, promotes and coordinates activities among thousands of participating organizations from every corner of the planet. SEE ALSO ACTIVISM; HAYES, DENIS; NELSON, GAYLORD.

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Denis Hayes

Earth First!

Earth First! (EF!) is a network of environmental activists, living mostly in the United States, committed to preserving wilderness and biological abun-

Earth First Journal logo. (Courtesy of Earth First Journal. Reproduced by permission.)

dance. It was founded in 1980 by Dave Foreman, Mike Roselle, and a number of other environmentalists who were disillusioned with so-called mainstream environmentalism. Foreman and the others previously worked with Washington, D.C.–based environmental groups. According to EF! founders, however, these organizations were always willing to compromise their ultimate goals to be active players in the policy process. The founders of EF! sought to provide principles and a loose organizational structure for people who were no longer willing to compromise in their efforts to protect nature. The group's motto is "No Compromise in the Defense of Mother Earth!"

EF! is unique within the environmental movement for its philosophical orientation, political strategies, and organizational structure. EF! expounds the principles of deep ecology. At the heart of this view is the belief that all living things have intrinsic value, and thus one should protect the environment for the well-being of all creatures, not simply human beings. Put differently, deep ecology espouses a biocentric (life-centered) rather than an anthropocentric (human-centered) orientation.

A defining feature of EF! since its inception has been the commitment of many of its members to direct action and civil disobedience as ways to halt and call attention to environmentally harmful practices. Earth First! activists have occupied trees, blockaded roads, sabotaged bulldozers, and pulled up survey stakes to halt logging and mining in forests. Additionally, they have chained themselves to earthmoving equipment, cut down billboards, and otherwise harassed developers in attempts to stop specific instances of environmental destruction. These actions, often called "eco-tage" or "monkeywrenching," aim to disrupt forces of environmental harm in an immediate and dramatic manner. In its largest circulating publication, *Earth First! The Radical Environmental Journal*, Earth First! activists continually debate the merits of direct action with those who argue for symbolic forms of protest. This debate became extremely heated in the early 1990s when the popular Earth First! tactic of tree-spiking—driving nails into trees to damage logging equipment—came under fire after a saw operator was badly injured by a spike. Many renounced tree-spiking as a tactic, although monkeywrenching remains a signature tactic of EF! In addition to these more militant actions, Earth First! activists undertake ecological studies, debate environmental principles, sue corporations and agencies, and work to educate the public about threats to biological diversity and other environmental problems.

EF! describes itself as a movement rather than an organization. It shuns the corporate organizational structure of mainstream environmental groups, and thus has no hierarchical pattern of leadership. Rather, EF! consists of autonomous but cooperating elements through which people share information and coordinate action on various campaigns and projects. These campaigns include efforts to stop mining, grazing, and logging on public lands, and to end the discharge of pollution into coastal wild lands.

EF!'s achievements are matters of debate. Their direct actions have certainly raised business costs for developers, loggers, miners, and ranchers; its banner has enabled previously detached environmentalists to find comrades and likeminded supporters; its philosophical orientation has motivated many to become more radical in their commitment to environmental protection; and its mere existence has allowed more mainstream groups to appear more reasonable to legislators. At the same time, EF! has alienated some of the

more mainstream environmental groups, and has inspired backlash from antienvironmental forces. SEE ALSO Activism.

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Paul Wapner

Earth Summit

On June 3 and 4, 1992, the Earth Summit (formally the United Nations Conference on Environment and Development or UNCED) met in Rio de Janeiro, Brazil, as a twenty-year follow-up to the United Nations Conference on the Human Environment (UNCHE, held in Stockholm). The goal of the 120 heads of state, over ten thousand government delegates, and hundreds of officials from UN organizations was to refocus global attention on the planet's degradation. It was the largest gathering of heads of state in history.

Although the post-Stockholm years were marked in many industrialized countries by the incorporation of environmental protection in their policy-making processes, change in economically less developed countries was much slower. There, although, environmental protection objectives were understood as inseparable from economic development, they were often subordinated to it. In this context, with the winding down of the Cold War and such high-profile environmental problems as the Chernobyl nuclear disaster in 1986 and the *Exxon Valdez* oil spill in 1989, industrialized countries—led by Norway and Canada—and various think tanks and UN-sponsored studies called for a redirection of attention to global environmental issues. Most notably, the World Commission on Environment and Development's report entitled *Our Common Future* contended that it was "futile to attempt to deal with environmental problems without a broader perspective that encompasses the factors underlying world poverty and international inequality." Called the Bruntland Commission, after its chair Gro Harlem Bruntland, the commission's specific recommendations, presented to the UN General Assembly in 1987, included a call for a convention on environmental protection and sustainable development.

To help achieve this goal, in December 1989 the General Assembly formally agreed to convene another global conference, which came to be known as the Earth Summit. Even before the General Assembly met, the Canadian government proposed that Maurice Strong serve in the same capacity in 1992 as he had in 1972, as secretary-general of the conference; he was appointed to this position in February 1990. Strong chose as chair of the conference's preparatory committee (PrepCom) Tommy Koh, of Singapore, known for his masterful chairing of the Third Law of the Sea conference where he brokered North–South, East–West and land-locked coastal state differences.

Much of the preliminary work for the conference was conducted by PrepCom, which held four substantive sessions from August 1990 to April 1992.

At the Earth Summit, conferees agreed on a comprehensive global blueprint for sustainable development called Agenda 21 and on two sets of general principles: the Rio Declaration on Environment and Development and the Forest Principles. As well, two binding conventions that had been negotiated separately from Agenda 21 were signed: the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity.

Although such a listing of outcomes looks impressive, a number of related facts must be taken into account. All the key documents had been diluted in the process of achieving consensus. On central issues such as population, energy, forest production, and consumption, Agenda 21 was weakened to the point that it had little clout left. Also, the conventions on climate change and biodiversity were little more than frameworks, leaving the tough, substantive issues to the future. And former U.S. President George Bush refused to the sign the Convention on Biodiversity because of compensation requirements for countries that provide plant and animal sources for biotechnology inventions. He stood virtually alone among the leaders of the industrialized world in refusing to accept a climate change convention with definite targets. The European Union had sought to limit carbon dioxide emissions to 1990 levels by 2000.

Perhaps even more significant, and certainly of greater disappointment to delegates from developing countries, was the inability of UNCED to muster the financial commitments necessary to support all of Agenda 21. While developing countries had hoped to obtain commitments for subsidized technology transfer, debt relief, and an increase in official development assistance, the agreement reached at Rio did not commit countries to any new financial support. On the other hand, several industrialized countries pledged to provide some additional resources, and UNCED agreed to restructure the World Bank's Global Environmental Facility (GEF) in ways that would make it somewhat more acceptable to economically less developed countries. For example, GEF decision-making procedures would be more transparent and local governments more involved in GEF project development and administration.

In Rio, nongovernmental organization (NGO) activity took two forms. At the governmental conference, there were more than 1,400 NGOs accredited, including NGO observers within fifteen national delegations. In addition, there was a separate global forum, which involved a series of technical, scientific, and policy meetings and an unprecedented exercise in parallel treaty writing conducted by an international network of NGOs called the International Forum of NGOs and Social Movements. Although forum participants did not receive a chance to present their treaties to the summit and their press conference was poorly attended, the forum provided an international platform for many organizations that are often ignored, short of resources, or actively suppressed in their home countries. Most important, it proved to be a significant catalyst for post-Rio NGO activity.

The focus of post-Rio follow-up attention has been the Commission on Sustainable Development (CSD). Its mandate includes, but is not limited to, the monitoring and implementation of Agenda 21. It also involves monitoring activities related to environmental and developmental goals throughout

the UN system, receiving and analyzing information from governments and NGOs, enhancing dialogue with NGOs, and reviewing financial and technology commitments and the implementation of environmental conventions. From the outset, however, the CSD appeared to lack some of the necessary ingredients to fulfill its wide-ranging mandate. For example, because of political disagreements, national reports to the commission were not required, even though such reports have proven valuable for other UN monitoring bodies. Thus, it is not surprising that a December 2001 report issued by UN Secretary-General Kofi Annan concluded that "progress towards the goals established at Rio has been slower than anticipated and in some respects conditions are worse than they were ten years ago." As in the past, the UN hopes that a global ad hoc conference—in this instance the 2002 World Summit on Sustainable Development—would reenergize global efforts proved overly optimistic. SEE ALSO Treaties and Conferences.

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Michael G. Schechter

Economics

Economics is a social science that is applied to the production, distribution, exchange, and consumption of goods and services. Economists focus on the way in which individuals, groups, businesses, and governments seek to efficiently achieve economic objectives. General economics can be divided into two major fields:

- *Microeconomics*, or price theory, explains how the interaction of supply and demand in competitive markets creates a variety of individual prices, profit margins, wage rates, and rental changes. Microeconomics assumes that people behave rationally, and that consumers generally spend their income in ways that give them as much pleasure as possible. For their part, capitalists are viewed as seeking as much profit as possible from their operations.
- *Macroeconomics* deals with modern explanations of national income and employment. British economist John Maynard Keynes (1883–1946) explains macroeconomics as the total or aggregate demand for goods and services by consumers, business investors, and governments.

Economics of Pollution

The study of the economics of pollution as it relates to the environment must begin with an understanding of the nature of the economic system. This starting point is essential to any analysis of pollution economics because the basic cause of environmental problems is a specific type of market (economic) system failure.

Four Market System Goals

All economic systems that are formulated by various economists consider four central objectives: efficiency, equity, stability, and growth. *Efficiency* and *equity* concern the processes of production and consumption (and are concepts that fall under microeconomics). *Stability* and *growth* apply to the overall performance of an economy (and are concepts that fall under macroeconomics). When analyzed economically with regard to pollution (or any other subject), these four goals must be considered as interrelated.

Efficiency. The concept of efficiency is defined as the maximum consumption of goods and services given the available amount of resources. Perfect efficiency occurs when the market resolves *all* production and consumption decisions so that the market allocation of resources is such that all goods are being produced at the lowest possible cost. No government intervention is necessary in this scenario. In the complex U.S. economic system, perfect allocation efficiency is impossible.

One of the critical conditions for the analysis of pollution economics is that all costs and benefits be registered (or known) in the marketplace. With regard to pollution, environmental damage has resulted when all costs have not been recorded in the marketplace, either because they were ignored or, more recently, due to the fact that these costs cannot be properly defined. For example, the price of a gasoline-powered vehicle does not include the indirect costs that result from its production and use, such as air pollution and resultant health care. When such environmental damage is defined, then the government must intervene by regulating pollution, funding sewage treatment plants, and other such unmeasured production costs.

Equity. The concept of equity refers to the just (or equitable) distribution of total goods and services among all consumers. People own resources (such as their expertise and talents, along with property and land) that can be used in the production process. The more resources an individual owns, the more income that individual usually generates. This equitable distribution of income does not always hold in the real world. Economists, so far, have not developed a good theory of "equitable income distribution." As a result, equity considerations are generated on a need-by-need basis, usually by government actions such as minimum wage laws, social security benefits, and unemployment insurance.

The correction of existing pollution problems involves equity issues. What is fair to all those involved? The value of human and physical resources will be affected by changes in environmental regulations. For example, if a coal mine is forced to close because of environmental abuses, its workers will suffer. However, other local employees who work at the hydroelectric power plant will benefit directly with better wages and indirectly with cleaner air, water, and land. The coal mine workers will not consider this new arrangement very "equitable" in the redistribution of income, nor will the fishing business sector when fish cannot travel up the river past the dams to reproduce.

Stability. The concept of stability is defined as a system's ability to maintain a balance. A real-life economic system, such as in the United States, tends to be unstable. Adjustments in monetary and fiscal policies at the federal, state, and local levels are constantly being made. These policies are essential in order to strive for full employment and price stability.

Improvements in pollution control and prevention have far-reaching implications in economic stability. Large capital expenditures may be required for companies to install new pollution abatement equipment as ordered by the government. This action forces new capital and operating costs on such firms and—if large enough—can subject the macroeconomic system to instabilities.

Growth. The concept of growth refers to a system's ability to increase in size or intensity. The ability to regularly achieve economic growth must be present in economic systems. Standards of living will increase as long as the rate of output growth exceeds the rate of population growth. Again, a government acts within an economic system to provide ways (such as tax laws to promote the creation of capital goods) to provide stability.

Growth is the one goal that has been viewed critically by environmentalists. The more growth an economy generates, the more pollution it also generates. In theory, the more restraint that the government places on industry with respect to pollution controls, the more likely it is that those companies will decrease their growth rate. Society is then faced with a choice: more goods or less pollution. In fact, the U.S. economy demonstrated robust growth over the past several decades, despite an array of environmental laws and regulations that have cut pollution significantly.

Marginalism

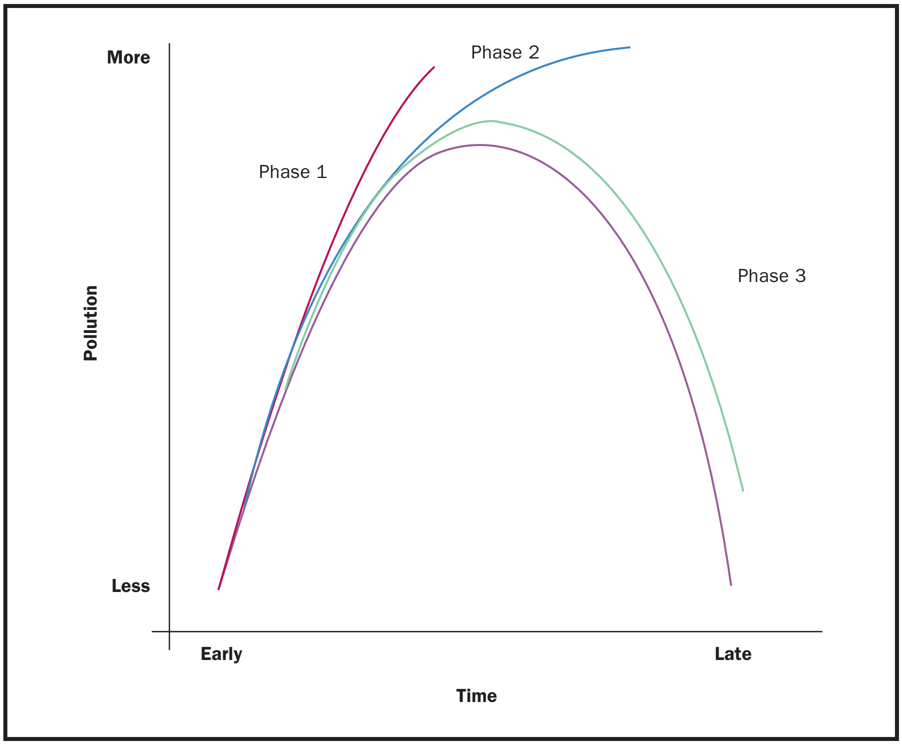
One of the basic economic approaches is *marginalism.* This approach seeks a level of operation of some activity that will maximize the net gain from that activity (which is the difference between its benefits and costs). During any activity, the benefits and costs increase, but because of diminishing returns, costs will generally rise faster than benefits. At its maximum level, *marginal costs* (the cost of increasing the activity) equal *marginal benefit* (the benefit of increasing the activity) so the activity is said to be optimized, or maximized. In other words, further expansions will cost more than it is worth, and further reductions will reduce benefits more than it will save costs.

Pollution. Marginalism is easy to apply to pollution in the theoretical sense. Unfortunately, it becomes difficult to apply in the real world because of the inability to accurately estimate the cost and benefit functions of pollution. Realistically, pollution is not a question of "having" versus "not having," but rather what *level is optimal.* This is where marginalism can prove useful, when used accurately and when taking into account all facets of the problem. Even in this context, reducing the level of pollution will affect other areas.

For example, manufacturing car tires that last about 64,000 kilometers (roughly 40,000 miles) at a cost of $200 might contribute 3 percent to the smog in Detroit, Michigan, whereas manufacturing tires that survive approximately 96,000 kilometers (60,000 miles) at a cost of $300 might add 9 percent to Detroit's smog. Even though the consumer is able to buy tires that last 20,000 miles (or 50 percent) longer and only cost $100 more (representing an increase of 50 percent) than standard tires, it is not as good a deal for the smog count, which triples from 3 to 9 percent.

Self-regulating Economic System

Another concept that affects pollution is the self-regulating economic system. Under ideal conditions all the information necessary for making the best



decisions is known. If a manufacturer made a product with thorough knowledge of *all* costs of production, including environmental costs, then ideal decisions could be made. But, of course, this is not possible.

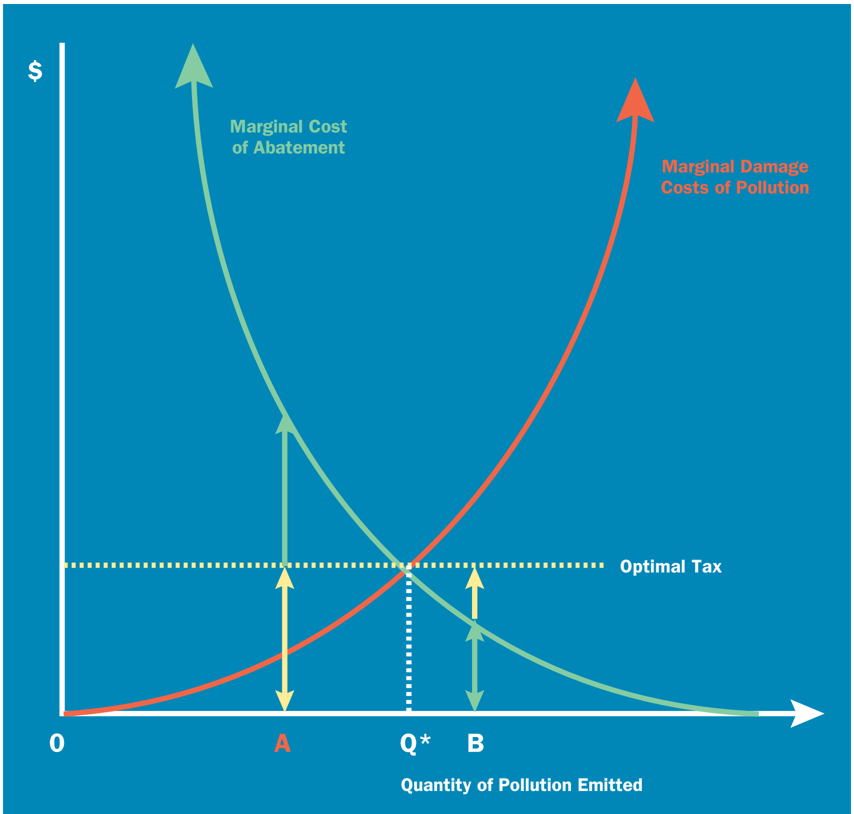
The efficiency of the competitive market depends on private costs (such as direct manufacturing expenses) and social costs (such as resulting pollution) being the same. When they are not equal, and when some of the costs are not known (i.e., some costs of pollution), the competitive market is not able to run at its maximum social efficiency. Thus, the failure to factor in all costs and benefits in the market can lead to pollution and environmental deterioration. Such inefficiencies of the market have produced pollution in many forms, including greenhouse gases and radioactive wastes.

U-shaped hypothesis. A widely held view by environmental economists is that economic growth does inevitably lead to the increasing pollution of air, water, and land. However, a diversion of resources to pollution control and general environmental objectives will eventually follow. That is, as prosperity increases (based on rising gross domestic product per capita), a more closely watched environmental program slowly replaces the former lack of concern with the environment. Evidence of this inverted U-shaped graph is already clear in many developed countries, such as the United States and England. See the graph for an an illustration of the hypothesis.

In phase one a country begins to develop, and growth (increasing at a rapid pace) exceeds pollution. Greenhouse gases, radioactive wastes, and pollution in small bodies of water start to increase. In phase two a country begins to mature, and pollution equals growth (although growth continues to increase). Pollution and wastes have accumulated and pollution becomes noticeable in larger bodies of water, such as oceans and seas. In phase three a country recognizes its pollution problems, and pollution is allowed to

Inverted U-shaped hypothesis.

SETTING THE OPTIMAL CARBON TAX LEVEL



At A marginal cost of abatement exceeds paying the fee so pay fee and pollute. At B the fee is more than the marginal cost so abate and don't pollute.

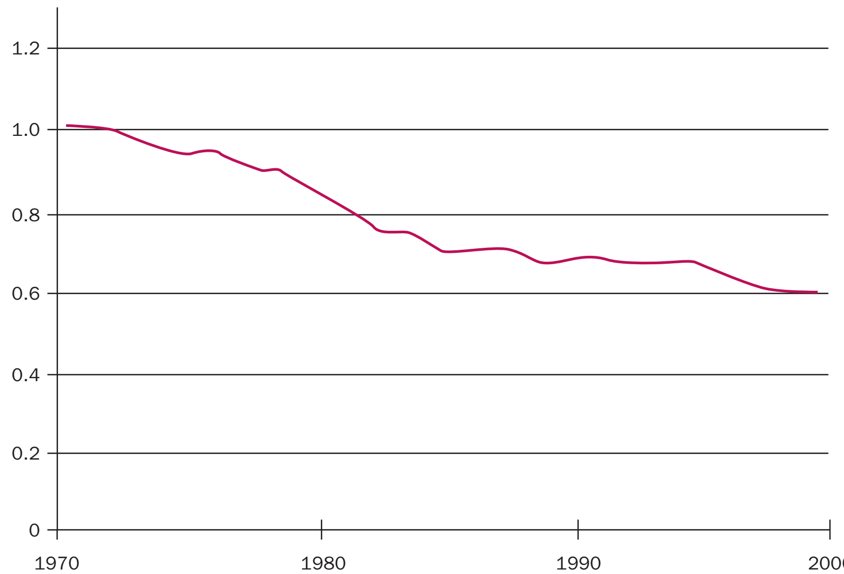
SOURCE: Graph developed by Professor Elizabeth Bogan at the Princeton Department of Economics.

decrease along with increasing growth. Measures to counteract pollution are instituted, such as sanitation, treatment, regulations, and zoning.

Measuring Pollution

Determining pollution problems and costs in the United States (or any country) may appear relatively simple. Unfortunately, this is far from the truth. In reality, there is generally a lack of accurate and comprehensive information on the condition of the environment in industrialized countries (and even more so in developing countries). In general, a lack of sufficient understanding by scientists of environmental phenomena and the elements in which to measure them still does not allow a comprehensive definition and evaluation of critical data. For example, it is easy to estimate the cost to fishers who have a reduced catch based on industrial pollution in the waters. But there are other, less straightforward costs to be considered, such as the loss of recreational opportunities on those waters and the loss of consumers in the consumption of those fish. In addition, it is difficult to know whether all the pollution came from industry, or whether other sources such as agricultural

ENERGY USE PER DOLLAR OF GROSS DOMESTIC PRODUCT 1970–2000



While the U.S. Gross Domestic Product increased from $1 trillion in 1970 to $10.3 trillion in 2000, the energy intensity of the U.S. economy decreased by 40%. Before 1970, energy use had increased hand in hand with growth in the economy.

SOURCE: Annual Energy Review 2000; DOE Energy Information Administration.

runoff were just as guilty. On the positive side, sufficient data are available that can be used to evaluate the major sources of pollution.

Pricing Pollution

One way to measure pollution is to place a price on it. Under such a system, anyone could emit pollution as long as one paid a set price for it. In this way, an approximate marginal social cost of pollution is established and decisions can be made based on that knowledge. Pricing pollution can simplify the process of dealing with pollution, and in the long run, provide a comprehensive and efficient way of handing the problem.

Any effort to restore and maintain the integrity of the environment imposes a burden on society with respect to additional costs. The magnitude and complexity of those costs are of great importance. To understand these costs and the benefits that a better environment can provide to society, economists study and analyze pollution through the methods of environmental economics. By doing this, society, in general, is forced to question the relationship between the institutions of society and the environment. In no certain terms is that relationship an easy one to study; it also makes a final determination of short-term—and even more difficult—long-term solutions hard to ascertain.

How can society best establish a high quality of life? The answer might be to enjoy pure mountain streams, breathe in clean air, and hike in pristine forests; the answer, however, might also be to enjoy good food and drink, comfortable housing, and convenient transportation systems. Environmental economics helps to determine the combination that individuals or groups

believe is most desirable. SEE ALSO Cost-benefit Analysis; Energy Efficiency; Enforcement; Ethics; Lifestyle; NAFTA (North American Free Trade Agreement); Poverty; Waste, International Trade in.

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William Arthur Atkins

Ecoterrorism

Ecoterrorism refers to the use of violence of a criminal nature against innocent victims or property for environmental-political reasons. Often of a symbolic nature, acts of ecoterrorism are usually committed by individuals who believe that the exploitation of natural resources and **despoliation** of the environment are becoming so severe that action outside of conventional legal and environmental channels is required.

despoliation deprivation of possessions by force

Using disruptive actions to call attention to an issue is hardly an invention of modern times, and radical environmentalists have taken their cue from the larger arena of sabotage and extreme civil disobedience. Modern radical environmentalists saw themselves inheriting the 1960s mantle of the Weather Underground and the Students for a Democratic Society (SDS) in using "direct actions" to put pressure on corporations, universities, and government agencies to adopt environmentally friendly policies.

Although vandalism and property destruction are clearly illegal, the issue of whether it is morally defensible to use such tactics is complicated. A 2001 Gallup Poll shows that a majority of Americans favor strong environmental protections over unfettered economic growth, and a 2002 League of Conservation voters poll showed that 81 percent of voters support either stronger environmental regulations or stricter enforcement of existing environmental laws. This public opinion may contribute to a romantic view of ecoterrorists, with their actions seen as part of a Robin Hood–like struggle—the weak fighting back against the strong. Such a view has been evidenced in popular culture for the last few decades, for example, in Edward Albee's 1975 novel *The Monkey Wrench Gang*. Others, usually corporations, trade associations, and property owners, see ecoterrorists as criminals, on par with revolutionaries and anarchists.

Key Players

Ecoterrorism occurred as early as 1977, when disaffected members of Greenpeace formed the Sea Shepherd Conservation Society and began a campaign of cutting fishing vessels' drift nets. However, the group of radical environmentalists best known for extreme tactics as a key part of their strategy is Earth First!, formed in the early 1980s. The American branch of Earth First! gained notoriety for its tactic of tree-spiking, whereby a large metal spike was driven into the trunk of a tree destined for logging. When loggers' saws hit such a spike, they would be damaged beyond repair, forcing the workers to stop, slowing the rate of logging, and costing the timber companies time and money. Although Earth First! insisted that it meant no harm to the loggers, several workers were injured with spikes, and some of the popular support for Earth First! waned as a result. Eventually, the group was forced to abandon its tactic of tree-spiking.

When Bill Clinton was elected president in 1992, environmental groups anticipated an administration sympathetic to their concerns, and their rhetoric lost some of its stridency. In reaction to this seeming weakening of resolve, a more radical offshoot of Earth First! renamed itself the Earth Liberation Front (ELF). ELF sees its actions as a matter of self-defense: protecting the earth from the greedy individuals and corporations that it views as destroying the environment's ability to sustain life. Since the ELF sees the perpetrators as committing violence against the environment, it feels justified in using violence in the form of economic sabotage, in order to "remove the profit motive" from environmental destruction. Law enforcement and some lawmakers, however, view ELF (and its sister organization, the Animal Liberation Front or ALF) as nothing more than garden-variety terrorists.

Effectiveness of Ecoterrorism and Law Enforcement Response

By financial standards, ecoterrorists have been very effective. ELF's campaign of property destruction has cost some $43 million since 1996, including the 1998 firebombing of the Vail, Colorado, ski resort that resulted in $12 million in damage. It has also generated considerable media attention in order to air its grievances. However, ELF has been less successful at stopping or slowing the development it seeks to prevent. In fact, those who have had property destroyed often feel a renewed resolve to continue with their projects so as "not to give in to terrorists." Of the sixteen major actions taken by the ELF in 2001, none have resulted in the permanent closure of a business or facility. The Vail ski resort, in fact, was rebuilt on a larger scale.

Very few ELF activists have been caught so far, due in large part to the anonymous and decentralized structure of ELF. Each cell operates individually and anonymously, and only notifies the ELF press office after an action has occurred. This strategy has frustrated the FBI and other law enforcement agencies, who have referred to the ELF as the nation's number one domestic terrorist threat. Although ELF claims that one of its primary rules of engagement is to cause no harm to any human or animal, the FBI Counterterrorism Division has argued that the frequency and intensity of its actions are increasing, and it is only a matter of time before someone is killed. The FBI may have some fears on that ground: ELF, along with a British group called Stop

Arson damage at a ski resort in Vail, Colorado. (© Affleck Jack/Corbis Sygma. Reproduced by permission.

Huntingdon Animal Cruelty (SHAC), has openly espoused more violent actions and stated that they may no longer hold the line against harming humans. In addition, congressional hearings chaired by Rep. Scott MacInnes of Colorado on February 12, 2002, called on mainstream environmental organizations to disavow ecoterror groups like ELF.

The FBI has also formed joint terrorism task forces with local police around the country to investigate ELF actions. However, although COINTELPRO, the official FBI domestic counterintelligence program, was mothballed in 1971, some environmental groups feel that they have been harassed by FBI investigations of their legal activities, such as demonstrations and protests. Furthermore, they assert that the FBI has intentionally bungled its investigations of violence against environmentalists, such as the 1990 Oakland car bombing of former Earth First! activists Judi Bari and Darryl Cherney. In June 2002, a federal jury agreed, awarding $4.4 million to Cherney and the estate of Bari, who died of cancer in 1997. Whether the new Department of Homeland Security will inherit the COINTELPRO mantle remains to be seen.

A new nonprofit group, Stop Eco-Violence, formed in Portland, Oregon, to demonstrate the harm of ecoterrorism to communities where it occurs. Stop Eco-Violence hopes to expose the terrorists and their funders, and assist law enforcement agencies by serving as a public clearinghouse to track ecoterrorism cases.

Conclusion

The ultimate morality of ecoterrorism remains uncertain, mirroring the larger debate of whether the use of violence is justified for a good cause. Most

mainstream environmental groups decry sabotage tactics in favor of public education, and law enforcement agencies will continue to prosecute those responsible for acts of ecoterrorism. However, there are those who believe that without such tactics, economic pressures will destroy the environment and all its resources. SEE ALSO ACTIVISM; TERRORISM.

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Elizabeth L. Chalecki

Education

Environmental regulatory organizations such as the U.S. Environmental Protection Agency (EPA) have historically dealt with pollution problems through control or remediation, as opposed to the pollution prevention (commonly called "P2") approach. However, treating pollution at its source can minimize, and sometimes eliminate, pollution. Environmental education is one effective, proactive strategy to implement P2.

An Educated Public

One goal of environmental education is to educate the public so that it is better informed to handle the issues and problems regarding pollution, whether it comes from industry, agriculture, or from the home. Educational programs, classes, pamphlets, and other informational products provide the public with the necessary skills to make informed decisions and take responsible action.

For instance, activities at the community level are often successful with such grassroots projects as school environmental curricula, hazardous waste collection days, and stream and river cleanups. However, environmental education programs are often at the mercy of public funding such as at the federal and state levels and of private donations and contributions.

Reasons to Learn

An important purpose of environmental education is to teach understanding about pollution in order to best protect the environment. Thus, groups involved with environmental education often teach individuals and groups pertinent information about subjects, such as biology, geology, meteorology, and hydrology, in order to better analyze the various sides of an issue through critical thinking. For example, members of the North American Association for Environmental Education (NAAEE) use a wide variety of materials and methods in order to investigate the environment within the context of economics, politics, popular culture, and social equity (just to name a few) as well as natural systems and processes in order to better educate the public.

Although the EPA is specifically constrained from creating environmental education curriculum, its leadership firmly believes that environmental education can help to:

- Protect human health
- Promote sustainable development (environmental protection and pollution prevention in conjunction with economic development)
- Create interest in a wide variety of jobs in various environmental fields
- Enhance learning in all areas of education
- Reinforce the desire to protect natural resources for future generations

Outreach Efforts

As a response to the growing pollution problem in the United States and other countries, outreach programs have been set up by various government agencies and nongovernmental organizations (NGOs) to promote the awareness and prevention of pollution. This educational strategy is effective at reducing (and even eliminating) pollution so that it requires less regulation, monitoring, and cleaning up.

The EPA has organized cooperative programs with the Peace Corps, the North American Association for Environmental Education, the Institute for Sustainable Communities, and other organizations to provide training, technical help, and information distribution to aid the international development of environmental education programs. These programs have been successfully used in Eastern and Central Europe, and in South and Central America.

On a smaller scale, JT&A, Inc., distributes EnviroScape™, three-dimensional landscapes that illustrate residential, agricultural, industrial, recreational, and transportation areas. All landscapes contain possible sources of water pollution, so that children learn by interacting with drink mix (which simulates chemicals) and cocoa (which simulates loose soil) just how

their actions affect the quality of water. Hands-on demonstrations allow complex problems to be simplified. Besides being used in elementary schools, the demonstrations are also used by universities, soil and water conservation districts, municipal governments, utility companies, environmental consultants, and environmental groups.

National Pollution Prevention Roundtable

The National Pollution Prevention Roundtable (NPPR) is one of the largest NGOs in the United States devoted exclusively to P2. It provides a national forum for the dissemination of P2 information with regards to policy developments, practices, and resources in order to diminish or eradicate pollution at the source. The NPPR provides its P2 members—federal agencies, state and local government programs, regional resource centers, small businesses, nonprofit organizations, and industry associations—with up-to-date and accurate P2 information. An important aspect of the NPPR is its National Pollution Prevention Week, commonly called "P2 Week," which is held nationally in the third week of September.

When the public is educated about pollution, businesses become more competitive, businesses and governments realize cost savings, individuals play a more informed role, and, in the end, environmental quality of life is enhanced by a reduction of pollution.

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William Arthur Atkins

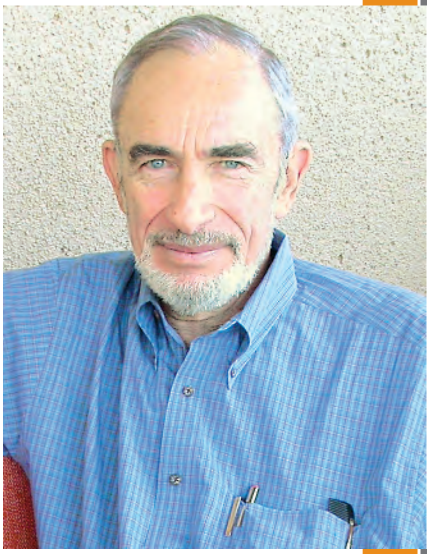
Ehrlich, Paul

AMERICAN WRITER, PROFESSOR OF ENTOMOLOGY AND HUMAN ECOLOGY
(1932–)

In 1968, Paul Ehrlich wrote *The Population Bomb*, which argued that human population growth was the root cause of society's environmental problems. Written in just three weeks, the book was a modern redefinition of the **Malthusian hypothesis**. Curiously, Ehrlich never mentioned Malthus in his book.

Malthusian hypothesis idea that populations always grow faster than their food supply, from Thomas Malthus

The Population Bomb became one of the best-selling environmental books of all time. Its main message was that continued population growth would place tremendous stress on natural resources and the environment. He predicted that, as a result, society would face war, famine, pestilence, and general calamity. Ehrlich asserted that only drastic governmental measures could curtail the impending disaster. He suggested a national Department of Population and Environment to police population growth and, in some instances, order mandatory sterilization. He expressed strong opposition to the antiabortion doctrines of the Catholic Church and the profit motive and aggressive consumption of the free enterprise economic system.



Paul Ehrlich. (Photograph by Gerardo Ceballos; courtesy of Paul R. Ehrlich. Reproduced by permission.)

The Population Bomb made Ehrlich a celebrity. His views found support largely from the academic community. Many others, including the Catholic Church and the African-American community, vehemently opposed his ideas and his drastic solutions that seemingly sought to curtail free choice. Despite the controversy, *The Population Bomb* succeeded in focusing attention on the important problem of human population growth. For example, in 2002 the global population is estimated at 6.2 billion people and, given established rates of growth, is expected to double in about fifty years. Most of this growth will be in the world's poorest countries. Ehrlich continued his studies of human ecology and wrote more than five hundred articles and books on the subject. He sustained his concerns regarding overpopulation, although his preference for draconian solutions diminished with time. He has received numerous honorary university degrees and awards for his contributions to modern environmentalism. Ehrlich is a founder and Honorary President of Zero Population Growth, a nonprofit organization working to slow population growth and achieve a balance between Earth's people and Earth's resources. Since 1977, he has been Bing Professor of Population Studies at Stanford University. SEE ALSO MALTHUS, THOMAS ROBERT; POPULATION; ZERO POPULATION GROWTH.

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Joseph E. de Steiguer

Electric Power

Power is defined as the energy that is consumed or converted in a certain amount of time. In a simple electrical circuit, the power is found by multiplying the voltage and current. An electric current is the movement of charged particles measured in amperes and the voltage of the force driving them. Current that flows in one direction only, such as the current in a battery-powered flashlight, is called direct current. Current that flows back and forth, reversing direction again and again, such as household current, is called alternating current. Household electricity bills are computed on the basis of how many thousand-watt hours (kWh) of energy are consumed over a certain period of time. Today's home consumes, on average, between twelve hundred and two thousand kWh per month.

Most of the world's electric power is generated in steam plants. In a steam turbine generator, fossil fuel, such as coal, oil, natural or synthetic gas

Two lines of horizontal axis wind turbines create energy on a wind farm in Altamont Pass, California. (Kevin Schafer/Corbis-Bettmann. Reproduced by permission.)

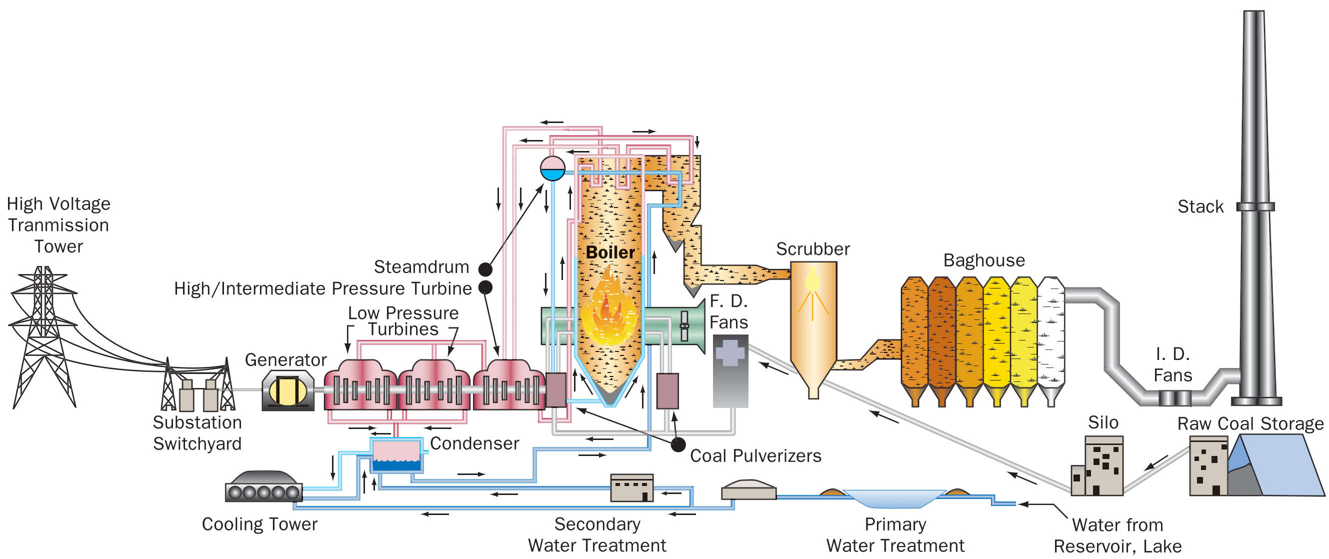
are the most common fuels used. Coal-based generation produces about 45 percent of all electricity generated in the United States, and natural or synthetic gas about 35 percent. The remaining, approximately 20 percent of generated electricity derives mostly from nuclear power plants, but includes wind, solar, biomass, diesel, geothermal, hydro, and other sources.

In a power plant, electricity is generated when a loop of conducting wire rotates in a magnetic field. Burning coal or gas produces hot steam that is forced through a turbine, causing it to spin. The spinning motion drives the generating coils within a magnetic field to produce electricity. Modern electricity-generating plants usually have a series of turbines to more effectively utilize the steam heat. The hot water returning to the boiler is used to preheat the fuel, allowing more efficient firing. See the illustration for a diagram of how electricity is generated by burning coal.

An electric power system consists of six main components: the electric power generating plant; a set of transformers at the plant to raise the generated electricity to the high voltages used on the transmission lines; the transmission lines; the substations at which the power is stepped down to the voltage that can be distributed to consumers; the distribution lines; and the transformers that lower the distributed voltage to the level needed by residential, industrial, and commercial users.

New gas turbine generators (analogous to big jet engines) are now being built that burn natural or synthetic gas as it is injected directly into the turbine system. This reduces heat loss and increases the efficiency of the fossil fuel.

HOW ELECTRICITY IS MADE



Among the most modern systems are coal gasification or **biomass** gasification, which produce synthetic gases (syngas) by refining coal or biomass in a high-heat, pressurized system (gassifiers). Syngas is a more efficient fuel and contains less pollutant than either biomass or coal. Nitrogen and sulfur products are captured in the conversion process and become industrial and agricultural chemicals. At present, these systems remain expensive to build and much of the technology is still being improved. However, gasification systems are becoming more competitive with coal- or gas-fired steam plants as the costs of pollution abatement continue to rise.

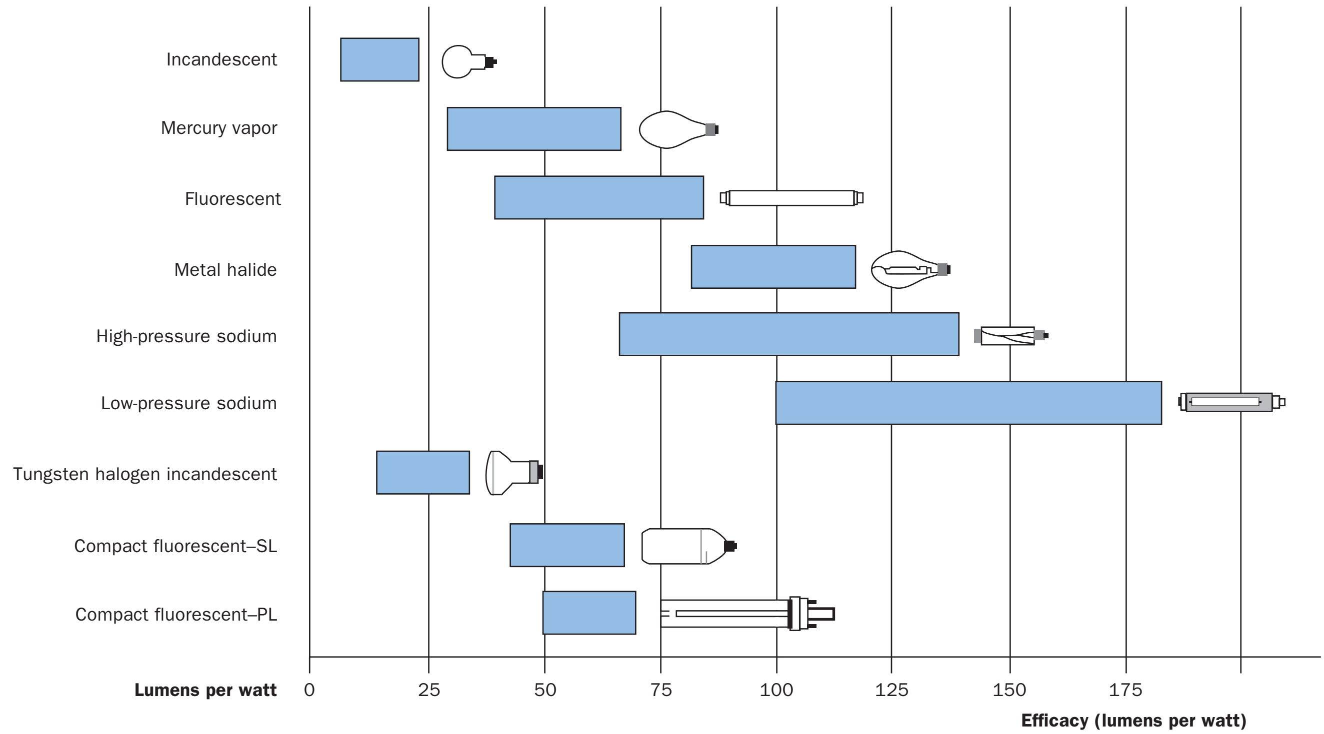
biomass all of the living material in a given area; often refers to vegetation

As energy is converted to electricity, it flows to a transmission station where transformers change a large current and low voltage into a small current and high voltage. The electricity flows over high voltage transmission lines to a series of transmission stations where the voltage is stepped down by transformers to levels appropriate for distribution to customers.

Coal has the lowest heat values (**British thermal units (BTUs)** or BTU per ton) of any of the common fuel sources in the world today. When it is burned to generate steam, the major pollutants are sulfur, nitrogen, very fine ash, and mercury. The amounts of sulfur and nitrogen emitted when coal is burned depend on the kind of coal and where that coal is mined. In the United States, high-sulfur coal is mined in the Appalachian region, New York to Kentucky and the region south of the Great Lakes, Illinois, Iowa, and Kansas. These are the **bituminous** coal types, with high BTU per ton. Low-sulfur coal is mined in the Midwest and the intermountain regions (Wyoming, Colorado, Utah, and the Dakotas). This coal is mostly bituminous and subbituminous. Subbituminous coal has a lower BTU per ton rating. The nitrogen content of coal varies significantly and does not have the unique geographic distribution of sulfur. Finally, in the Dakotas, there is lignite, which is literally carbon-based earth. It has a very low BTU per ton rating, and is one of the most abundant coal types in the northern Great Plains.

British thermal unit (BTU) unit of heat energy equal to the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit at sea level

bituminous soft coal, versus the harder anthracite coal



The energy performance of lamps is expressed as efficacy which is a measure of light output, in lumens, per watt of electrical input (lumens per watt). The efficacy of a regular incandescent light bulb is only a fraction of the efficacy of a flourescent bulb.

Pollution from electric power generation depends on the type and source of fuel. The emissions, when not captured, produce oxides of nitrogen, commonly referred to as NO_x, and sulfate aerosols from sulfur and oxygen, commonly referred to as SO_x. Both pollutants are chemically unstable when emitted into the atmosphere and combine with oxygen and moisture to form the SO_x and NO_x particulates that are recognized as the pollutants. NO_x is highly reactive with other pollutants found in urban and industrial areas and, with sunlight, forms smog. SO_x is often attributed as the primary source of acid deposits across the landscape, particularly in the northeastern United States, which is downwind from power plants in the Midwest.

Mercury is emitted as elemental mercury vapor. It settles only a short distance from the stacks of power plants. However, it very quickly changes to a methyl mercury form, and when it settles into water, streams, lakes, or cooling ponds, it is absorbed by plants and transferred up the food chain to fish and waterfowl eaten by humans. Although the total annual tonnage is small, science is showing that extremely small amounts of mercury can cause significant harm to humans, particularly the unborn and very young children.

Most ash from burning coal is collected at the bottom of the fire box. However, very fine ash can float out of the smokestack. The particle size that concerns present-day regulators falls in the 10 micron and 2.5 micron range. A micron is one-thousandth of a millimeter. Airborne particulate this small may be contributing to increases in childhood asthma. Electric power generation is not the only source of such particulates in urban and suburban

areas. Vehicle emissions from gasoline and diesel engines are also significant contributors.

The ash residual from burning coal is often suitable for the production of road surfaces, some forms of concrete, and lightweight blocks used to reduce erosion along rivers and streams. Once considered a pollutant or waste and dumped into open pit coal mines, coal ash is now becoming a valuable commodity.

Pollution Abatement

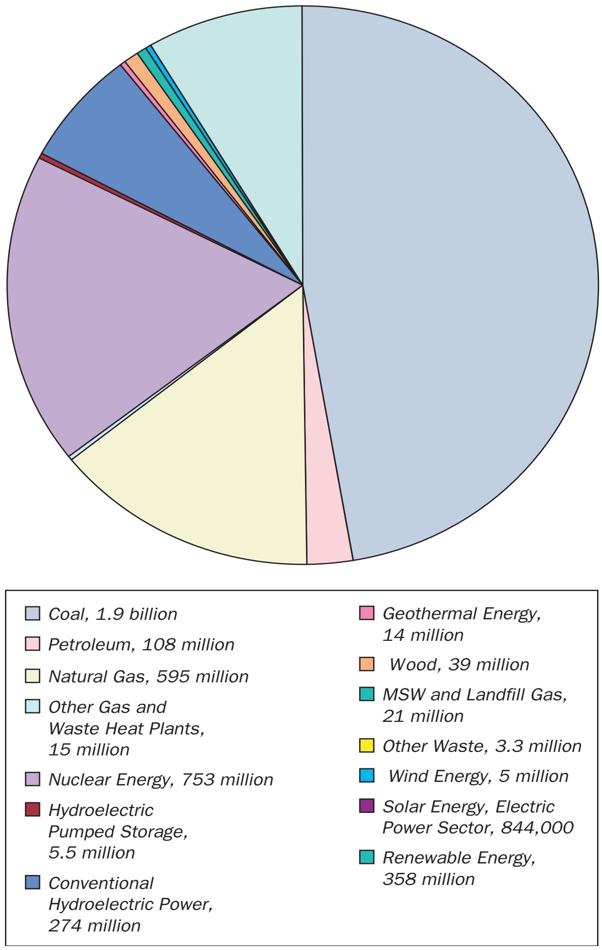
Sulfur and nitrogen are captured by passing the hot gases from the combustion chamber through filters and water baths or by selective catalytic converters, thus removing them from the heat passed up the smokestack. The fine ash from the burning process is also filtered by a huge vacuum system with bags able to filter particles as fine as face powder. The concern about emissions of mercury is leading to the design of new systems capable of capturing the mercury vapor before it is released from the smokestack.

Environmental air quality standards are continually changing as new information about potential harm is published. It is a continual struggle between electric power generators and regulators to write and meet pollution standards that protect the environment and human health. Changes to a modern coal-based generator or even a natural gas generator cost thousands of dollars per megawatt of generating capacity. This means that every update, which must be designed onsite, as there are no standardized units, results in millions of dollars in additional costs. A steam generation system is designed to last at least fifty years, with initial investments close to a billion dollars, but because continually shifting requirements for pollution reduction systems cannot be incorporated in its design at the time of construction, the costs of later upgrades are almost inevitably incurred.

Electricity consumption has continued to rise approximately 2 to 5 percent per year as more and more electrical appliances are required to meet daily needs. Paying attention to the efficiency of each appliance, from computers to air conditioners, helps reduce the rate of increase. The higher the efficiency, the less total growth in individual consumer electricity use. More efficient lights, such as compact fluorescent bulbs, can effectively reduce the per capita use of electricity. Most electrical equipment manufacturers now provide comparisons of various appliances, machines, or other power equipment so informed consumers can make efficient choices. The U.S. Environmental Protection Agency (EPA) has a program called Energy Star that rates the efficiency of various appliances, computers, and other equipment. Those manufacturers that are compliant with high-efficiency standards receive an Energy Star stamp of approval.

Deregulation offers opportunities to independent power producers developing green electric power companies, for example, wind, biomass, solar, geothermal, and hydroelectricity generation, that wish to assure consumers their power source will not contribute to the increasing consumption of fossil fuels or emission of greenhouse gases. Such opportunities will, however, continue to come at a slightly increased price over the next decade before technologies to produce green power become more efficient, more

2002 ELECTRICITY NET GENERATION BY FUEL SOURCE



generated power of this kind is widely available, and the costs of fossil fuels become more prohibitively expensive.

From 1950 to 1999, the most recent year for which data are available, annual world electric power production and consumption rose from slightly less than 1,000 billion to 14,028 billion kWh. The most commonly used form of power generation also changed. In 1950 about 66 percent of electricity came from thermal (steam-generating) sources and approximately 33 percent from hydroelectric sources. In 1998 thermal sources produced 63 percent of the power, but hydropower had declined to 19 percent, and nuclear power accounted for 17 percent of the total. The growth in nuclear power slowed in some countries, notably the United States, in response to concerns about safety. Nuclear plants generated 20 percent of U.S. electricity in 1999; in France, the world leader, the figure was 76 percent. See the pie chart for 2002 information on the net generation of electricity by fuel source. SEE ALSO Abatement; Acid Rain; Air Pollution; Cleanup; Coal; Energy; Energy, Nuclear; Fossil Fuels; Petroleum; Renewable Energy.

Gary R. Evans

Electromagnetic Fields

The potential health effects of human-made electromagnetic fields (EMFs) have been a topic of scientific interest since the late 1800s, particularly in the last twenty years. Electromagnetic fields are natural phenomena that have always been present on earth. However, during the twentieth century, environmental exposure to human-made EMFs increased steadily, predominantly due to increased electricity and wireless technology use. Nearly all people are exposed to a complex mix of different types of weak electric and magnetic fields, both at home and at work.

EMFs can be broadly divided into two categories: extremely low-frequency electric and magnetic fields (ELF EMFs), common sources of which include power lines, household electrical appliances, and computers; and high-frequency or radiofrequency electric and magnetic fields (RF EMFs), of which the main sources are telecommunications and broadcast facilities, and mobile telephones and their base stations.

Electrical currents exist naturally in the human body and are an essential part of normal bodily functioning. Nerves relay signals by transmitting electric impulses, and most biochemical reactions, from those associated with digestion to those involved in brain activity, proceed by means of rearranging charged particles.

ELF EMFs influence the human body just as they would any other substance consisting of conducting materials and charged particles. ELF EMFs may induce circulating currents within the human body. The strength of these induced currents depends on the intensity of the outside magnetic field and the size of the loop through which the current flows. When sufficiently large, these currents can cause **neural** and muscular stimulation (among other **biological effects**). However, at the EMF exposure levels normally found in the environment, the currents induced in the body by ELF EMFs are much weaker than those occurring in the body naturally.

At RFs, the main biological effect of EMFs is heating, the same effect that microwave ovens utilize. The levels of RF EMFs to which people are normally exposed are far lower than those need to produce significant heating.

Research Conclusions

ELF EMFs. In 2001, the International Agency for Research on Cancer (IARC) evaluated studies to determine whether ELF EMFs could increase cancer risk. Using the standard classification that weighs laboratory, human, and animal evidence, magnetic fields were classified as possibly **carcinogenic** (potentially cancer-causing) to humans based on **epidemiological** studies of childhood leukemia. Evidence for all other cancers, as well as for exposure to static and electric fields, was considered insufficient. "Possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans, and insufficient evidence of carcinogenicity in experimental animals. This classification is the weakest of three categories ("carcinogenic to humans," "probably

BODY CURRENTS

Electrical currents exist naturally in the human body and are an essential part of normal bodily functioning. Nerves relay signals by transmitting electric impulses. Most biochemical reactions, from those associated with digestion to those involved in brain activity, proceed by means of rearranging charged particles.

neural related to nerve cells or the nervous system

biological effects effects on living organisms

carcinogen any substance that can cause or aggravate cancer

epidemiology study of the incidence and spread of disease in a population

> ***PRECAUTIONARY APPROACH***
>
> Strategy to reduce risk when information about potential risk is incomplete. For cell phones, one advisory panel, IEGMP, recently recommended the adoption of a precautionary approach: discouraging the use of mobile phones for nonessential children's calls. They noted that if there are currently unrecognized health effects from the use of cell phones, children might be more vulnerable. Anyone concerned might limit exposure by reducing the length of calls or using "hands-free" devices to keep mobile phones away from the head and body.

carcinogenic to humans," and "possibly carcinogenic to humans"). For reference, gasoline exhaust and coffee have also been classified as possible human carcinogens. Despite the classification of ELF magnetic fields as possibly carcinogenic to humans, it remains possible that there are other explanations for the observed association between exposure to ELF magnetic fields and childhood leukemia. Research and evaluation of this issue are continuing.

RF EMFs. For higher-frequency fields, the balance of evidence to date suggests that exposure to RF EMFs, such as those emitted by mobile phones and their base stations, does not cause adverse health effects. Some scientists have reported minor effects of mobile phone use, including changes in brain activity, reaction times, and sleep patterns. These effects, however, are small and appear to lie within the normal bounds of human variation.

Current debate and research are centered on whether long-term, low-level exposure (below thermal) can cause adverse health effects or influence people's well-being. Several recent epidemiological studies of mobile phone users found no convincing evidence of increased brain cancer risk. However, the technology is too recent to rule out possible long-term effects. Mobile phone handsets and base stations present quite different exposure situations. RF exposure is far higher for mobile phone users than for those living near cellular base stations. However, apart from infrequent signals used to maintain links with nearby base stations, handsets transmit RF energy only while a call is being made, whereas base stations are continuously transmitting signals. Given the widespread use of technology, the degree of scientific uncertainty, and the levels of public apprehension, rigorous scientific studies are needed. SEE ALSO CANCER; HEALTH, HUMAN; RISK.

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Leeka Kheifets and Nathan Thrall

Emergency Planning and Community Right-to-Know

The Emergency Planning and Community Right-to-Know Act (EPCRA) is also known as SARA Title III since it was enacted as a freestanding law included in the Superfund Amendments and Reauthorization Act of 1986 (SARA). This law obligates facilities to provide local, state, and federal

agencies with information on hazardous materials stored or in use at the premises. EPCRA covers four key issues: emergency response planning, emergency release notification, reporting hazardous chemical storage, and toxic chemical release inventory (TRI). It, however, in no way limits what chemicals may be used, stored, transported, or disposed of at a facility. EPCRA was enacted in response to the chemical disaster in Bhopal, India, where residents and emergency responders were unaware of and unprepared for the lethal chemicals in their immediate environment.

The State Emergency Response Commission (SERC) and Local Emergency Planning Committees (LEPCs) must be given information concerning facilities in their area where hazardous substances are stored and/or are in use. This information is vital for the development of emergency plans to address the accidental release of toxic chemicals. Facilities must immediately notify the SERC and LEPCs of the release of hazardous material in excess of set regulations. EPCRA also requires facilities to maintain a data sheet enumerating all the hazardous materials at their workplace; they must submit it to the SERC, LEPCs, and local fire departments. Finally, facilities must provide an annual inventory listing releases or other waste management procedures involving hazardous chemicals.

Facilities and/or individuals that do not adhere to the rules established by the EPCRA can face fines and prosecution under the law. EPCRA requirements are aimed at providing communities with the information they need should an accidental release of hazardous material occur through a fire or explosion, for instance. SEE ALSO DISASTERS: CHEMICAL ACCIDENTS AND SPILLS; DISASTERS: ENVIRONMENTAL MINING ACCIDENTS; DISASTERS: NATURAL; DISASTERS: NUCLEAR ACCIDENTS; DISASTERS: OIL SPILLS; TOXIC RELEASE INVENTORY.

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Lee Ann Paradise

Emissions Standards *See Air Pollution*

Emissions Trading

Emissions trading brings the rules of the marketplace to environmental regulation. For example, a government trying to control acid rain might set a limit of ten metric tons on emissions of sulfur dioxide SO_2 (which causes acid rain) in a particular year. If there are 1,000 electric utilities, it might give each utility 10,000 “allowances,” each of which allows the utility to emit one ton of emissions during that year. In such a timeframe, if one dirty utility is able to reduce its emissions to 8,000 tons of SO_2, that utility can sell its

2,000 excess allowances to another cleaner utility that is quickly growing and for whom it might be prohibitively expensive to further reduce emissions because its operations were already quite clean. Both would benefit from this trade because the allowance value will be higher than what it cost the dirty utility to reduce emissions, but lower than what it would have cost the clean utility to achieve them. During the same twelve months the utilities would monitor their emissions; at the end of year they would be required to prove to the government that they had emitted fewer tons than they have allowances for. Total emissions are limited to ten metric tons but some flexibility exists in regard to which utilities actually reduce emissions. The kind of approach outlined in this hypothetical example makes it cheaper to achieve the target and may lead to stronger environmental controls in the future.

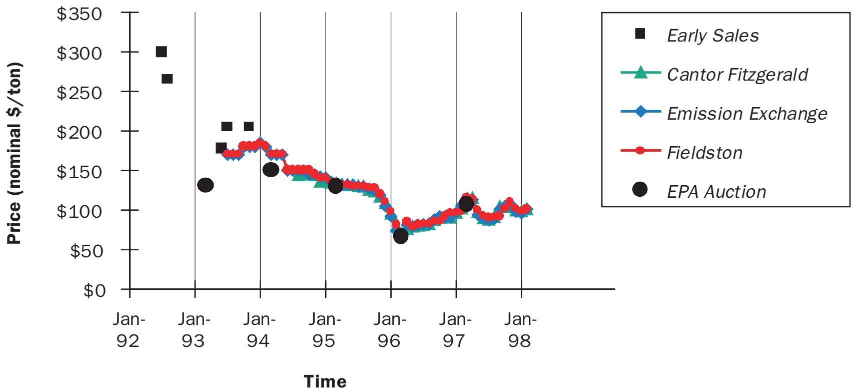
This is a simple system. There are some choices in how it is designed. First, the government does not need to give away the allowances; it could sell them to companies. This allows everyone else to benefit from the system. Second, if it does not matter whether emissions happen this year or next, the allowances could be "banked" for future use. For some pollutants, such as the greenhouse gases that cause climate change, what matters is the total accumulation in the atmosphere, not when or where they were emitted. For other pollutants such as carbon monoxide, which is poisonous at high concentrations but disperses quickly, when and where it is emitted is important.

Emissions trading is one of the key "flexibility mechanisms" in the Kyoto Protocol (signed in 1997) that aims to control climate change. In this case, governments jointly agreed on the total emissions cap and then decided how many allowances each country would receive. Countries may trade allowances, but they must monitor their greenhouse gas emissions and submit a report to the United Nations every five years to show that they have as many allowances as emissions. The United States did not sign the Kyoto Protocol. They argued that the U.S. target was too strict and, hence, too costly. They also argued that the agreement would have no value without the participation of developing countries.

Emissions trading is particularly useful when there are a lot of different emitters and when companies rather than the government know best how to reduce emissions or improve the technology to reduce emissions. In an emissions trading system, companies will use their knowledge to make the best economic decisions for themselves, while also meeting environmental standards in an efficient way.

Emissions trading is not effective when the exact location or method of disposal of the emissions does, in fact, matter (e.g., toxic waste disposal) or when the timing of emissions is critical (e.g., discharging hot water into a river causes substantial damage if a large amount is released all at once, but almost none if it is discharged very slowly). In these situations, environmental standards cannot be met if companies are allowed to trade because any movement or change in the timing of emissions would have significant effects on the environmental outcome.

Some environmentalists and observers have philosophical objections to "pollution trading." These concerns can be justified when the cap is poorly enforced, or when companies or countries are able to exploit others. When



SOURCE: MIT Center for Energy and Environmental Policy Research.

This illustration shows allowance prices up to and during the first three years of the U.S. Acid Rain program which commenced in 1995. Prices first were dispersed and unstable, but once the market became established, they converged. Prices initially fell as utilities identified cheaper opportunities for abatement.

markets are well designed, these philosophical concerns seem to decrease with positive experience.

Emissions trading is widely used in the United States. Examples include the acid rain program for controlling SO_2, the RECLAIM market for **criteria pollutants** in Los Angeles, and the new nitrogen oxides (NO_x) markets on the East Coast. The United Kingdom has introduced a form of carbon dioxide (CO_2) emissions trading as part of its effort to comply with the Kyoto Protocol. Many other European countries and the European Community (EC) as a whole are seriously considering carbon dioxide trading within the EC.

criteria pollutant a pollutant for which acceptable levels can be defined and for which an air quality standard has been set

The graph shows allowance prices up to and during the first three years of the U.S. Acid Rain program, which commenced in 1995. Prices were initially dispersed and unstable, but once the market became established, they converged. In the beginning, prices fell as utilities identified cheaper opportunities for abatement. SEE ALSO Acid Rain; Carbon Dioxide; Economics; Industry; NO_x (Nitrogen Oxides); Ozone.

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Suzi Kerr

Endocrine Disruption

In 1971 doctors at the Massachusetts General Hospital reported high rates of unusual cancers of the vagina in teenage girls. Researchers traced the problem to a medicine their mothers were given during pregnancy intended to help prevent miscarriage—a synthetic estrogen called diethylstilbestrol (DES). DES has also been linked to other health problems, ranging from vaginal and uterine malformations and immune problems in girls, to undescended testicles, sperm abnormalities, and possibly testicular cancer in boys exposed to DES before birth. DES is an example of an endocrine disruptor.

Endocrine disruptors are chemicals in our environment that interfere with **hormones**—natural chemical messengers that travel in the bloodstream and regulate many important physiological activities. Endocrine disruptors may be natural phytoestrogens (estrogenlike chemicals that are made by plants) or synthetic chemicals used in medications, dietary supplements, cosmetics, and household products. They may also show up in pollution. Some examples of endocrine disruptors are listed in the table "Examples of Endocrine Disrupting Chemicals."

hormone a molecule released by one cell to regulate development of another

The endocrine system, which regulates growth and development and controls important functions in humans and animals, includes hormones and **hormone receptors** distributed throughout the body. The hormone estrogen helps to regulate bone development, blood clotting, female puberty, the menstrual cycle, many of the changes that occur during pregnancy, and fetal development. The hormone testosterone helps male **fetuses** develop, regulates male puberty, and promotes sperm production. Thyroid hormones affect energy level, appetite, heart rate, and **metabolism** in adults. In fetuses and infants, thyroid hormones are essential for normal growth and the development of the brain. There are many other hormones that are less well known, but equally important, including hormones secreted by the hypothalamus in the brain, the pineal gland, the pituitary gland, the parathyroid glands, and the adrenal glands (see figure).

hormone receptors cell proteins that respond to hormones to influence cell behavior

fetus unborn young of vertebrate animals; human: developing child in the womb from eighth week to birth

metabolism physical and chemical reactions within a cell or organism necessary for maintaining life

Just as a woman's menstrual cycle returns to normal after she stops taking birth control pills, adult endocrine systems are often able to recover after exposure to artificial hormones. In the very young, however, short-term exposure can have permanent effects. Hormones regulate the normal development of organs such as the brain and reproductive system. Most scientists have therefore focused on the threat endocrine disruptors may pose to fetuses and infants.

Examples of Research on Endocrine Disruption

In 1987 researchers at Tufts Medical Center in Boston were studying breast cancer cells growing in plastic dishes in the laboratory, when they noticed that the cells began to grow rapidly as if exposed to estrogen, even when no estrogen was added to the dishes. They traced the problem to nonylphenol, a chemical leaching from the plastic laboratory dishes. Now researchers use breast cancer cells to test chemicals for **estrogenic** effects.

estrogenic related to estrogens, hormones that control female sexual development

In the early 1990s, scientists in Florida studying alligators living in a lake contaminated with **DDT** and related pesticides noticed that the male alligators had tiny penises and the female alligators had abnormal-looking ovaries.

DDT the first chlorinated hydrocarbon insecticide chemical name: Dichloro-Diphenyl-Trichloroethane); it has a half-life of fifteen years and can collect in fatty tissues of certain animals; for virtually all but emergency uses, DDT was banned in the U.S. in 1972

EXAMPLES OF ENDOCRINE DISRUPTING CHEMICALS

Chemical	Use	Mechanism	Health Effect
Diethylstilbesterol (DES)	Medication	Mimics estrogen	In humans – female – vaginal cancer, reproductive tract abnormalities; male – abnormalities of the penis and testicles, semen abnormalities
Genistein	Naturally occurring in soybeans	Mimics estrogen, blocks testosterone	In adult humans – lowers cholesterol, may decrease breast cancer risk. In animals – infertility.
Bisphenol A	Resin in dental sealants, lining of food cans, and polycarbonate plastics	Mimics estrogen	In male mice – alters prostate size, decreases sperm production, affects behavior
Vinclozolin	Pesticide/fungicide	Inhibits testosterone	In male rodents – feminization, nipple development, abnormal penis development
Polychlorinated biphenyls (PCBs)	No longer made; still found as a pollutant	Inhibit thyroid hormones	In humans – delayed neurological development; IQ deficits
Dioxin	By-product of industrial processes including incineration	Decreases estrogen; decreases testosterone; alters thyroid hormone	In female rodents – delayed puberty, increased mammary cancers. In male rodents – decreased testosterone, penis and testicular abnormalities, feminized sexual behavior. In humans – decreased thyroid hormone levels; decreased testosterone; cancers

Most of the alligator eggs in the lake did not hatch that year and this phenomenon has persisted into the twenty-first century. These effects may have resulted from pesticide **residues** in the alligators' food sources. Research has confirmed that DDT acts like estrogen when it enters the body, and that its **breakdown product**, DDE, blocks male hormones such as testosterone. Other pesticides in the lake have also been shown to mimic estrogen.

residue the dry solids remaining after evaporation

breakdown product part of a whole resulting from a chemical transformation

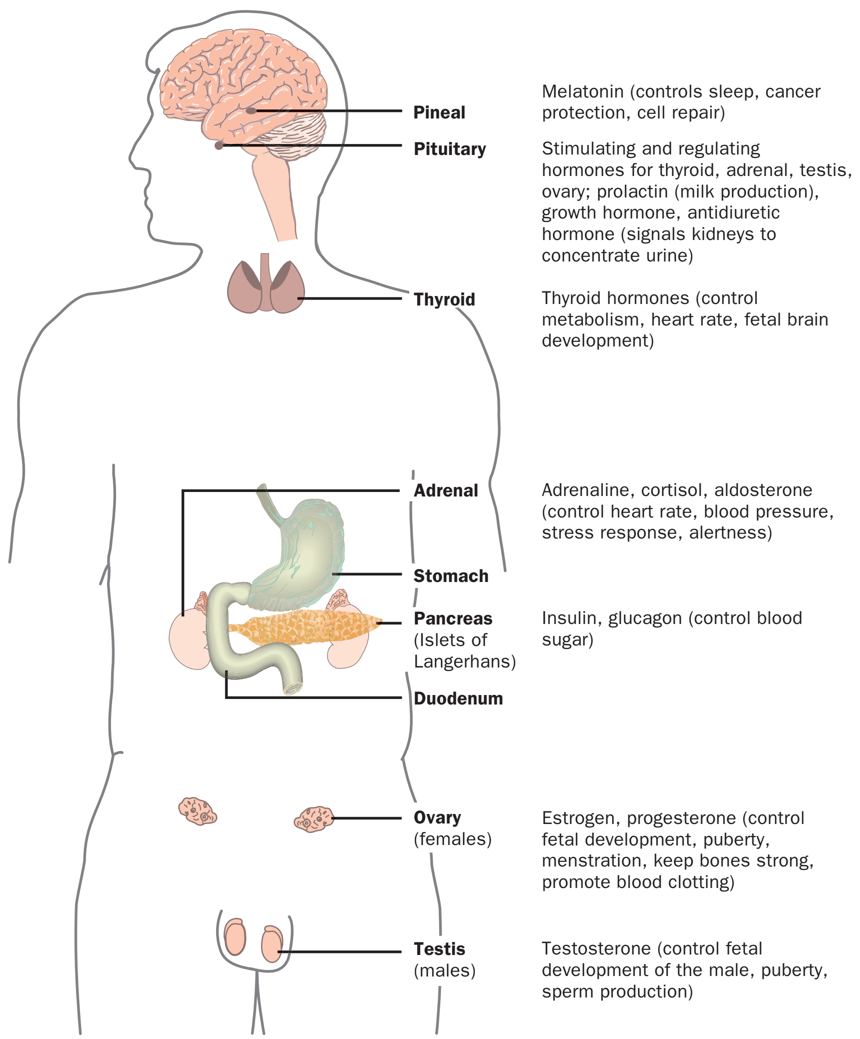
Polychlorinated biphenyls (PCBs) are environmentally persistent chemicals that interfere with thyroid hormones. The Great Lakes have been heavily contaminated with PCBs from industrial sources, leaking electrical equipment, and landfills. Researchers have observed that salmon in the Great Lakes have goiter (enlargement of the thyroid gland) and have trouble reproducing. Studies of children born to mothers who ate fish from the Great Lakes at least two times per month found that PCB levels in these mothers were higher than in women who did not eat Great Lakes fish. Their infants were born with abnormally small heads and showed signs of abnormal neurological development. Even when they were eleven years old, the exposed children had significantly lower IQ scores and were twice as likely to be two years behind their peers in their level of reading comprehension.

The Endocrine Disruptor Controversy

The theory that chemicals in the environment may be disrupting hormones and causing health problems in wildlife and humans was first published in 1992. Since that time, the general concept of endocrine disruption has gone from a radical theory to an accepted fact. Scientists agree that some chemicals mimic or block hormonal effects, that wildlife populations in some contaminated areas have been affected by the endocrine-disrupting effects of chemicals in the environment, and that some humans have been affected in unusual circumstances.

Scientific debates focus on whether there is a risk to the general population of humans and animals from the low levels of endocrine disrupting

THE ENDOCRINE SYSTEM



SOURCE: Adapted from John W. Kimball, *Biology Pages*. Available from http://www.ultranet.com/~jkimball.

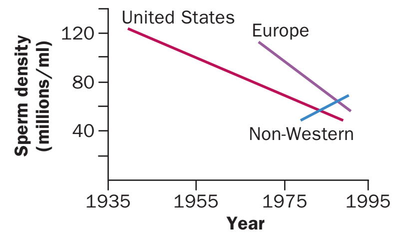
chemicals they are exposed to on a daily basis. Some scientists point out that even low levels of endocrine disruptors may have subtle effects on development of the fetus. These scientists point to trends such as apparent increases in rates of birth defects of the penis in infant boys, declining sperm counts in adult men (see the graph), and increasing rates of hormone-associated cancers such as breast, testicular, and prostate cancer. Other scientists point out that most endocrine disruptors are far weaker than our natural hormones, and that most people and animals are exposed to such low levels of the chemicals that they are unlikely to have any health effects. This debate is likely to rage for many years, because the research to prove or disprove health effects from low-dose exposures to common chemicals will be difficult, complicated, and time-consuming.

Because chemicals that are known or suspected endocrine disruptors are used for a wide variety of purposes, it is difficult for people to know how to

avoid exposure. Some endocrine disruptors are used as pesticides on food and others are used in certain types of plastics such as polyvinyl chloride (PVC or vinyl). These chemicals are not just found industrial and agricultural products, but also in the runoff of pesticides from treated fields and in the discharge of waste from industrial operations. Certain endocrine disruptors are not used anymore, but their residues linger in the food chain and are consumed by humans in the form of fatty foods. Because it is difficult for people to make decisions as to how to avoid exposure to endocrine disruptors, many environmental health advocates urge the government to regulate these chemicals more strictly.

In 1996 Congress passed the Food Quality Protection Act, changing how the U.S. Environmental Protection Agency (EPA) regulates pesticides and requiring the EPA to develop an endocrine disruptor screening program. The EPA estimates that there are some 87,000 chemicals used in commerce, and admits there is not enough scientific data available to evaluate all potential risks. SEE ALSO Health, Human; Pesticides; Risk.

SPERM COUNT DECLINE IN THE UNITED STATES AND EUROPE (1935–1995)



SOURCE: Adapted from http://www.ourstolenfuture.org/NewScience.

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Gina M. Solomon and Annette Huddle

Energy

Energy is the capacity for doing work. In physics, "work" has a more formal definition than in everyday life: it means the ability to exert a force through a distance. If you pick up this book, energy stored in molecular bonds inside your body is released to move the book's mass. The energy was stored in the molecules of the foods you ate and is released through a chemical reaction. Food provides the fuel that gives us energy.

Similarly, whether we are talking about automobile engines or power plant boilers, we need to have a fuel with stored energy that can be released in a useable way. Fossil fuels such as coal, oil, and natural gas provide much of the energy we use in industry and in our personal lives. These fuels were created by geological processes over millions of years, as plants and marine microorganisms consisting largely of carbon became buried under the earth. These fossilized materials were eventually transformed into coal or oil by the high pressures and temperatures inside the planet.

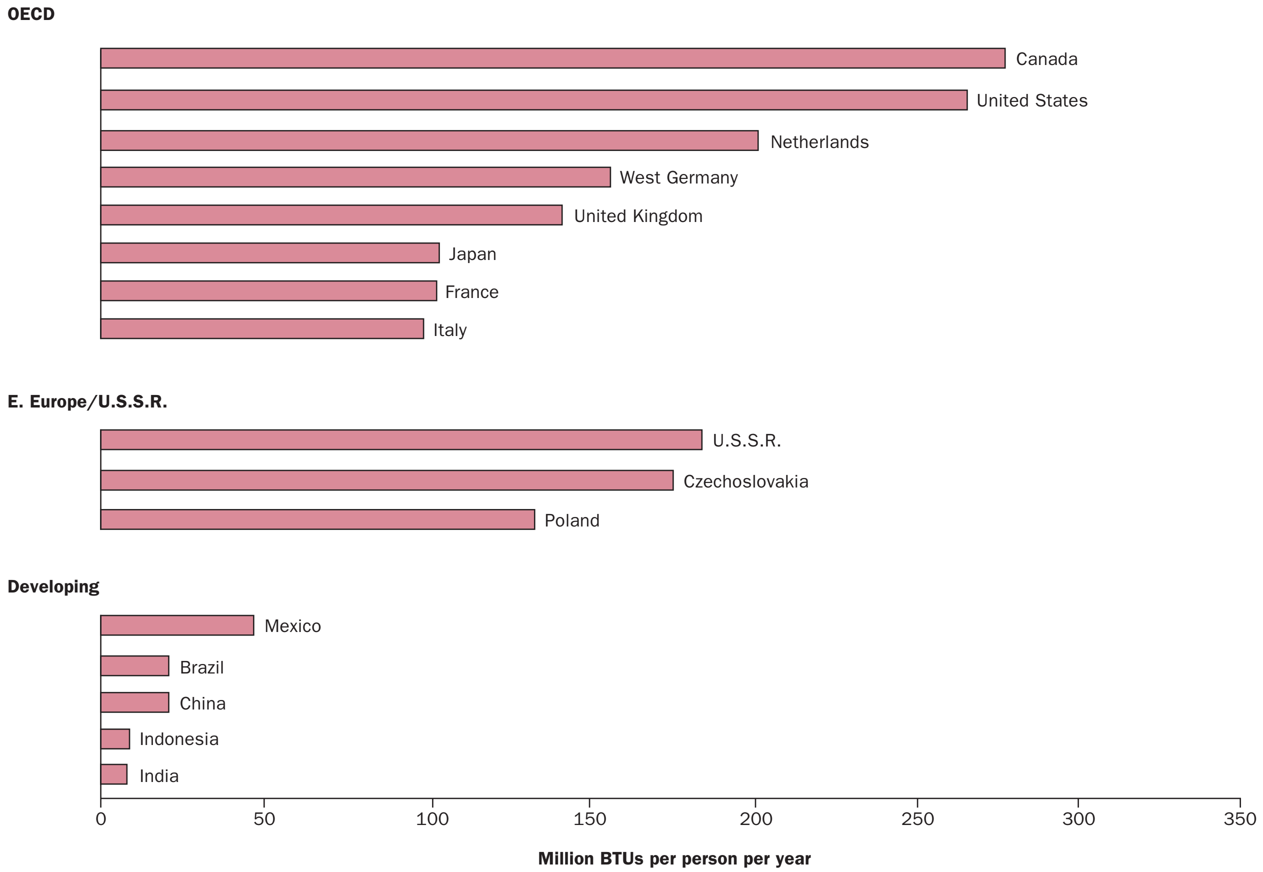
A coal-fired power plant. (©Lester Lefkowitz/Corbis. Reproduced by permission.)

Because of the long time and extreme conditions needed to create fossil fuels, we cannot just replace them at will—they are a nonrenewable resource. Every time we pump oil from the ground we are depleting an irreplaceable natural resource. Eventually, we will exhaust the supplies of fossil fuels in the earth, and we will have to develop alternative energy sources to power our society. Exactly when we will run out of fossil fuels is a subject of great debate. A careful distinction must be made here between "reserves" and "resources." Reserves are defined as economically recoverable with known technology and within a price range close to the present price; resources are theoretical maximum potentials based on geological information, and include reserves. The Energy Information Administration (EIA) of the United States Department of Energy has estimated the worldwide coal resources at 1,083 billion tons; the oil reserve at approximately 1,200 billion barrels, with resources estimated at three trillion barrels; and the worldwide natural gas reserve at 5,500 trillion cubic feet . The nonprofit Corporation for Public Access to Science and Technology (CPAST) in St. Louis, Missouri, has estimated from earlier data published in the *United States Department of Energy 1996 Annual Energy Review* that these combined fossil fuels resources would last until the year 2111 if usage remained constant at 1995 levels. The EIA predicts that coal resources could last for 220 years at the current usage rates. Estimates change when new technology makes fuel that was previously considered "unrecoverable" suddenly accessible; these numbers should only be used as rough guidelines.

Transforming Energy into Work: Gasoline Engines and Steam Boilers

Gasoline, which consists largely of hydrocarbon molecules—chains of connected carbon and hydrogen atoms—acts as a fuel in an automobile engine. It

PER CAPITA ENERGY CONSUMPTION



SOURCE: U.S. Congress, Office Technology Assessment, *Energy in Developing Countries*, OTA-E-486 (Washington, D.C.: U.S. Government Printing office, Jan. 19)

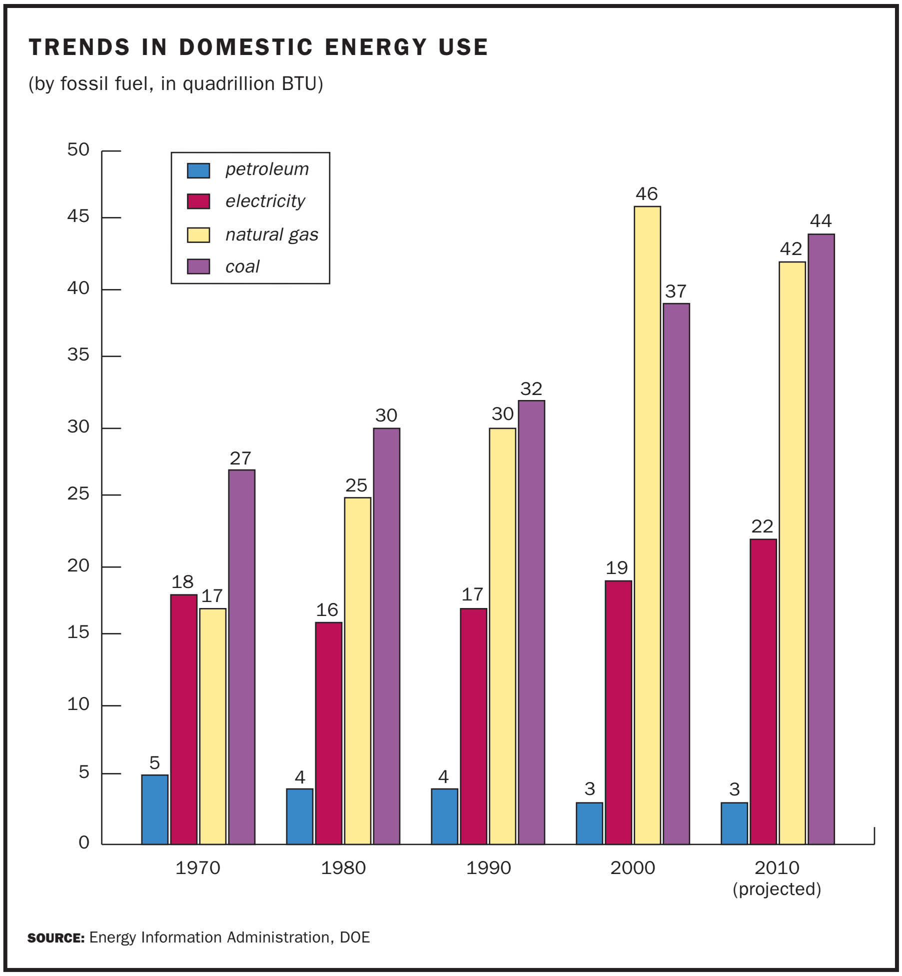
is a product of the distillation of raw petroleum. The energy that holds these carbon and hydrogen atoms together is stored in the bonds between each atom.

In an automobile, gasoline is mixed with air in the combustion chamber of an engine cylinder, the mixture is compressed by a piston, and a spark from the spark plug ignites the mixture. The ideal chemical reaction for this process is:

Hydrocarbons + oxygen + spark ⟶ carbon dioxide + water + energy

The energy is released in the form of heat, which causes the gases to expand and pushes the piston outward. The piston is connected to a rod and a crankshaft that ultimately transform the energy locked up in molecules into the revolution of wheels, setting your car in motion. The combustion products of carbon dioxide and water are expelled through the exhaust system into the atmosphere.

Similarly, a boiler in a power plant relies on the release of energy from burning coal or natural gas to heat water and convert it into steam. The steam turns the blades of a turbine-powered generator that ultimately causes electrons to move through a wire, converting the energy from the fuel into electrical energy that can be used to power appliances in your home.



In each of these cases, energy stored in chemical bonds is transformed into useful energy that can perform work.

Energy and Pollution

In addition, the chemical reaction shown above is an ideal one, but conditions in the real world are usually far from ideal. If the right amounts of oxygen and gasoline are not present in the cylinder of a car engine (because of a dirty air filter or a faulty fuel injection system, for example), poisonous carbon monoxide can form. Similarly, some of the hydrocarbons might escape from the engine unburned, releasing pollutants such as methane into the air. Nitrogen from the air inside the cylinder can combine with oxygen to form the pollutants nitric oxide and nitrogen dioxide, collectively know as NO_x compounds, which can be converted to ground-level ozone in the presence of sunlight. Even carbon dioxide—one of the "ideal" products of complete combustion in an engine or a power plant—has been identified as a "greenhouse gas" that is partially responsible for global warming.

The coal used in power plants does not emerge from the ground as pure carbon. It is laced with varying amounts of different contaminants, including sulfur, which vary from coal mine to coal mine. These, too, can find their way into the atmosphere as pollutants when the coal is burned to heat the water in a boiler. Most notably, sulfur oxide, emitted into the air, converts to sulfu-

ric acid, a major component in acid rain. Power plants are required to clean up these emissions before they reach the atmosphere, to varying degrees, but again, no process is 100-percent efficient.

Besides the pollutants associated with the use of fossil fuels, drilling for oil and mining coal can be an additional source of pollution. An oil spill while drilling or transporting oil can lead to disastrous ecological damage, and rain runoff from a strip mine can carry coal particles and chemical byproducts into the local water supply.

Nuclear and Alternative Fuels

Nuclear energy is not based on combustion of fuel. Rather, the energy is released as unstable radioactive compounds decay into more stable forms. For example, radioactive uranium 238 decays to uranium 235, releasing energy in the process. This energy can be used to heat water without burning coal or oil, so its use is therefore cleaner. However, radiation emitted in the event of an accident at a nuclear power plant could harm people and wildlife and contaminate the food supply. Nuclear waste, in the form of spent fuel rods, is a very long-term by-product of nuclear energy.

Cleaner-burning fuels can be produced by processing agricultural products ("biomass") into ethanol. Thousands of acres of corn could be grown specifically for energy production, not consumption by people or animals. Because the ethanol that results comes from a controllable chemical distillation process, it is very pure and uncontaminated, and thus burns cleaner. Also, because a new crop can be grown every year, these are renewable energy sources.

Hydropower, or the use of moving or falling water to generate energy, is one of the oldest technologies that still contributes significantly to our energy needs. Falling water was often used in old mills to turn a paddlewheel and move the heavy stones that were used to grind grain into flour. Later, the same concept was transferred to the production of electricity. Hydroelectric plants, such as the one in Niagara Falls, divert some of the water from the falls into the power plant. There the kinetic energy (the energy of objects in motion) of the falling water turns turbines and generates electricity that can be sold to residents and industrial users in the area.

Solar power, wind power, and fuel cells powered by a reaction of hydrogen plus oxygen to form water are other alternative energy sources that are being explored.

Industry and Environment

Suppose you are the owner of a manufacturing plant. You need large amounts of fuel to keep your plant running. To maximize your profits, you would like to purchase this fuel very cheaply. The cheapest option would be if the energy company could take the fuel straight from the ground and sell it to you "as is." But fossil fuels must be processed before they can be used. Petroleum products must go to the refinery to be separated into various components such as gasoline and diesel fuel, and contaminants such as sulfur have to be minimized. All these processing steps add cost to the fuel.

Even after you obtain a relatively clean fuel, your manufacturing process may result in pollutants that could find their way into the atmosphere or rivers. Again, efforts to clean up these emissions will cost you money. Chemical

U.S. ENERGY STATISTICS FOR THE YEAR 2000

Type of Energy	Percentage of U.S. Energy Pool	Contribution to Pollution (Percentage of Carbon Emissions)
Petroleum	38.8%	42.1%
Coal	23.0%	36.7%
Natural Gas	23.3%	21.2%
Nuclear	8.0%	n/a
Blomass	3.7%	n/a
Hydroelectric	3.1%	n/a
Electrical Imports	0.1%	n/a

SOURCE: Lawrence Livermore National Laboratory, Energy & Environment Directorate. "US Energy Flow 2000." Available from http://en-env.llnl.gov/flow.

The tiny town of Cheshire, Ohio, lives in the shadow of American Electric Power's giant coal-burning Gen. James M. Gavin generating plant. Each summer, blue clouds of sulfuric acid rain down on the town, an unintended and ironic by-product of AEP's efforts to curb other emissions at the plant. Residents sued and in 2002, AEP agreed to buy the town rather than fight the pollution suit. All but a handful of Cheshire's 221 residents have agreed to sell and move. The cost: $20 million.

systems that scrub the pollutants from the emissions, or filters that capture particulates, are expensive and raise your production costs.

But there may be people who are more concerned about a healthy environment than your profits. They might insist that you take whatever steps are necessary on both the inlet (fuel) side and the outlet (emissions and runoff) side to make the world a better, safer place to live. They may lobby to have laws passed that require you to clean up any emissions from your plant.

You want a clean environment too, but even the most environmentally conscious company must make a profit to stay in business. Environmental regulations add to the cost of producing your product, but this is no different than all the other costs you incur (raw materials, labor, transportation, marketing, etc.). If all competitors in an industry are constrained by the same regulations, then the playing field is level; every company in the field may have to raise its prices to make up for the added costs of compliance, but prices for similar products should remain competitive. However, if competitors in foreign countries are able to operate without these same environmental regulations, they can market their products more cheaply, and make it more difficult for domestic producers to stay in business. It is this kind of imbalance in regulations that lead to job losses, and give the mistaken impression that we must choose either jobs or the environment. If governments can maintain a level playing field in environmental regulations, we can have both jobs and a clean environment worldwide.

The situation may be further confused by an argument among scientists and health professionals as to how much of a health problem a certain chemical represents. Something that seems safe today may be discovered to be a health risk ten years from now. Until we understand how various chemicals interact with our bodies, there may be room for discussion on allowable levels of emission.

Conserving Energy

In light of the depletion of nonrenewable resources, it is important that we try to conserve energy whenever possible. Because the transformation of fuel into useful energy inevitably creates pollutants, we must reduce our energy consumption to reduce pollution. Using your air conditioner less during the summer by setting the thermostat higher can reduce the demand for electricity experienced by your energy provider. Your energy provider can burn less fossil fuel and still meet the needs of its customers, resulting in less pollution. Carpooling removes unnecessary vehicles from the road, reducing gasoline consumption and air pollution. Energy conservation efforts thus help at both ends of the cycle: they slow down the depletion of fuel reserves and, at the same time, clean up the environment.

The Politics of Energy

Because the conditions necessary for the creation of fossil fuels varied geographically throughout the earth's history, fossil fuels are not distributed evenly around the globe. Significant concentrations of oil occur in the Middle East, the North Sea, Russia, Texas, and Alaska, for example. Countries that control the world's access to oil have economic power over countries that need their oil, which can lead to political tensions. The "energy crisis" cre-

ated by the OPEC (Organization of the Petroleum Exporting Countries) nations in the 1970s, when they artificially reduced the supply of oil available on the world market, was a display of this political and economic power. Iraq's attack on Kuwait in 1991 to take over Kuwaiti oil fields led to the first Persian Gulf War. As long as there is uneven access to energy sources throughout the world, political tensions over the availability and cost of energy will continue. SEE ALSO Air Pollution; Alternative Energy; Carbon Dioxide; Coal; Disasters: Nuclear Accidents; Disasters: Oil Spills; Electric Power; Fossil Fuels; Nuclear Energy; Nuclear Wastes; Petroleum; Renewable Energy; Thermal Pollution.

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Tim Palucka

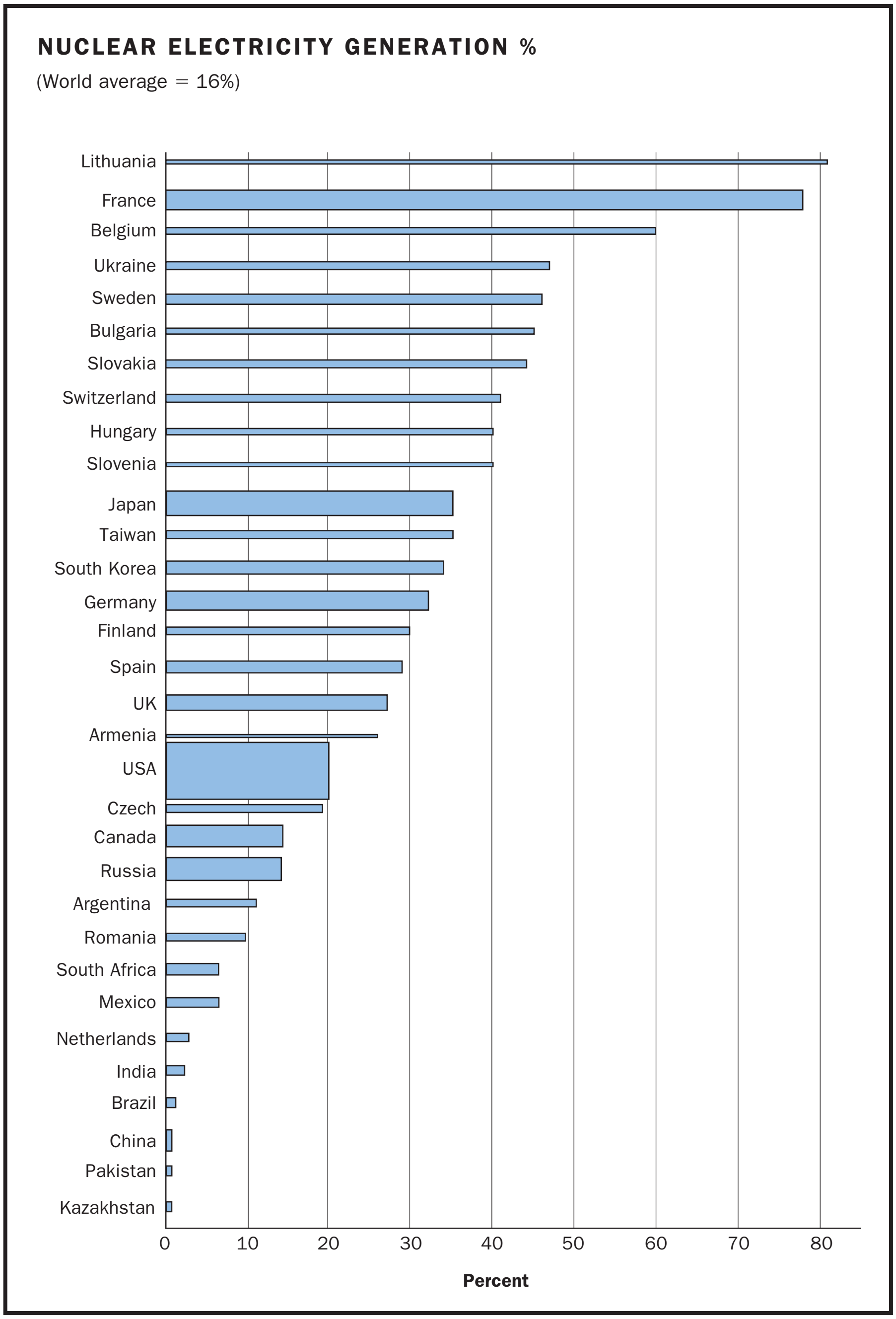
Energy, Alternative

See Renewable Energy

Energy, Nuclear

Nuclear energy is produced during reactions in the nucleus of an atom. Atoms can be thought of as miniature solar systems with the nucleus at the center like a sun and electrons orbiting around it like planets. Densely packed neutrons and protons make up the nucleus, which is held together with great force, the "strongest force in nature." When the nucleus is bombarded with a neutron, it can be split apart, a process called fission. Uranium is the heaviest natural element and has ninety-two protons. Because uranium atoms are so large, the atomic force that binds it together is relatively weak, so fission is more likely with uranium than other elements.

Fusion, another type of nuclear reaction, is the joining of atoms and can occur with elements of low atomic number, such as hydrogen, the lightest element, which has one proton. The first time physicists achieved fusion was in the 1950s with the hydrogen bomb. Fusion releases a tremendous amount

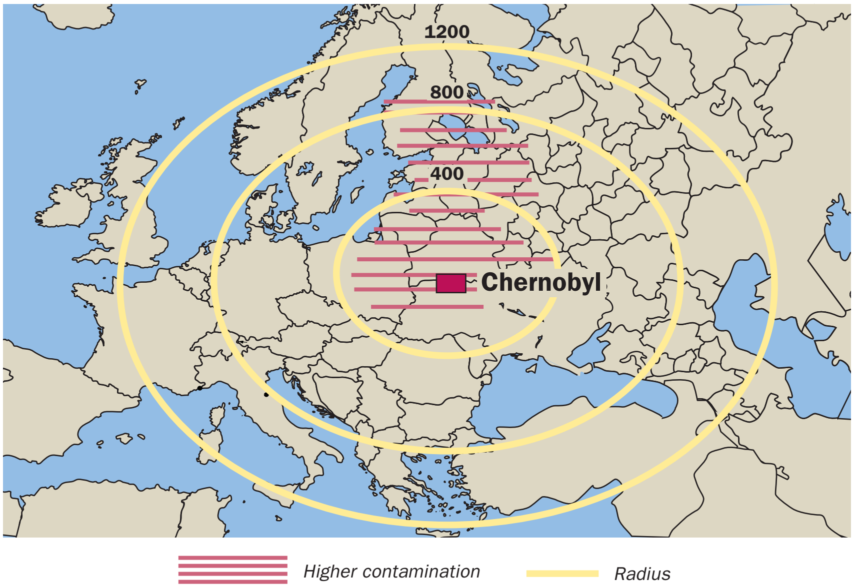


of energy, but the energy is released so quickly and uncontrollably that fusion has not yet been harnessed as a usable source of energy.

Physicists formulated the principles of nuclear power in the early twentieth century. In 1939 German scientists discovered the process of nuclear fission, triggering a race with American scientists to use the massive energy release of fission to create a bomb. The atomic bomb was created by the United States in 1945; it was used to destroy Hiroshima and Nagasaki in Japan at the end of World War II.

After World War II, atomic power was seen as a potential new energy source. The U.S. government thought atomic explosions would be a labor-saving way to dig canals and reservoirs and to mine for gas and oil. As late as

CHERNOBYL GLOBAL RADIATION PATTERNS



the 1960s, bombs were being set off above and below ground to test different ideas, resulting in radionuclide contamination of the soil that is still being addressed today.

A more successful use of atomic power was nuclear reactors that controlled the release of energy. Admiral Hyman G. Rickover guided the development of small reactors to power submarines, greatly extending their range and power. By the late 1950s, nuclear power was being developed for commercial electric power, initially in England. Morris, Illinois, was the site of the first U.S. commercial reactor. Nuclear weapons research was advanced by Russia and the United States during the Cold War, and a number of other countries, including China and India, have now developed nuclear weapons.

Nuclear Power Plants

Uranium is one of the least plentiful of minerals, making up only two parts per million (ppm) in the earth's crust. But because of its radioactivity, it is a plentiful supply of energy: one pound of uranium has as much energy as three million pounds of coal.

In 2002 there were 104 nuclear power reactors licensed to operate in the United States, and they accounted for 20 percent of the nation's electricity production and more than one-fourth of nuclear power capacity in the world. Many other countries, including France, Japan, and the United Kingdom, have nuclear power plants. Nuclear power accounts for about 80 percent of France's electrical power production.

How Nuclear Power Works

In nuclear power plants, neutrons collide with uranium atoms, splitting them. This split releases neutrons from the uranium that, in turn, collide

with other atoms, causing a chain reaction. This chain reaction is regulated (or governed) by "control rods" that absorb neutrons. Fission releases energy that heats water to approximately 520°F in the core of the plant. The steam that is created is then used to spin turbines that are connected to generators, which produce electricity.

After the steam is used to power the turbine, it is cooled off and condensed into water. Some plants use water from rivers, lakes, or the ocean to cool the steam; returning this water to the environment can cause thermal pollution. Other plants use the hourglass-shaped cooling towers that are the familiar hallmark of many nuclear plants. For every unit of electricity produced by a nuclear power plant, about two units of wasted heat are sent into the environment.

Nuclear reactors are also used to power military submarines and surface ships. As in land-based reactors, nuclear-powered vessels use the heat produced by the chain reaction to make steam for a turbine. The turbine is connected to the propeller shafts aboard the ships rather than generators that produce electricity.

Radioactive Pollution from Nuclear Energy

By 1995 over 32,000 metric tons of highly radioactive waste had been produced by American nuclear reactors. That number is expected to rise to 75,000 metric tons by 2015.

Before the mid-1970s, the plan for fuel removed from nuclear reactors was to reprocess it and recycle the uranium into new fuel. Because a by-product of reprocessing is plutonium, a highly unstable element that can be used to make nuclear weapons, President Jimmy Carter ordered the end of reprocessing in 1977 due to security risks. Reprocessing also had a difficult time competing economically with the production of new uranium fuel.

Since then, the U.S. Department of Energy (DOE) has been studying storage sites for the long-term burial of such waste and is now focusing on Yucca Mountain in Nevada. The DOE has built a full-scale system of tunnels in the mountain at a cost of over $5 billion. Although the Yucca Mountain site is still controversial, there are no other sites presently under consideration.

Meanwhile, radioactive waste continues to be stored at the nuclear plants where it is produced. The most common option is to store it in a large steel-lined pool. As these pools fill up, fuel rods are stored in large steel and concrete casks. SEE ALSO RADIOACTIVE FALLOUT; RADIOACTIVE WASTE; THERMAL POLLUTION; YUCCA MOUNTAIN.

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David Lochbaum

Energy Efficiency

Energy efficiency is a ratio of energy input to useful energy output, often expressed as a percentage. It measures how much energy of one kind is converted into usable energy of another kind. Incandescent light bulbs convert just 5 percent of the electrical energy they use to light, whereas the energy efficiency of compact fluorescent bulbs is between 15 and 20 percent. Power plants fueled by natural gas convert up to 50 percent of their heat energy to electrical energy, compared to about 38 percent for coal-burning power plants. Energy efficiency is never 100 percent, because some energy is always lost as heat, either directly or as a result of friction in between moving parts in such equipment as motors and generators.

The EnergyGuide label that is affixed to new appliances sold in the United States. (© 2003, Kelly A. Quin. Reproduced by permission.)

Energy Efficiency in Industry and Transportation

Increasing energy efficiency conserves fossil fuels, cuts down on pollution, and saves money. Steam turbine power plants reduce their energy or heat loss by insulating pipes and by returning condensed steam to the boiler for reheating. New combined-cycle plants increase energy efficiency by using hot exhaust from gas turbines to produce steam for steam turbines in the same plant. On-site electricity generators often increase energy efficiency by cogeneration, or by combined heat and power (CHP), in which waste heat is captured to heat buildings. Cogeneration is employed in many different industries, with chemical, paper, and petroleum refining plants being the largest users. A number of colleges have also installed CHP generators. Improved technologies, the use of **catalysts**, renewable or recycled raw material, and recovery and reuse of waste in industry increase energy efficiency.

catalyst a substance that changes the speed or yield of a chemical reaction without being consumed or chemically changed by the chemical reaction

In transportation, fuel efficiency or miles per gallon (MPG) depends on vehicle design, on reducing air resistance by reducing the weight of a vehicle, and on the type of fuel used. Carbon-fiber composites are strong, extremely light materials that could significantly increase fuel efficiency if employed in the manufacture of vehicles. One such material is waiting to be patented, and research into reducing composite production cost, using agricultural and paper-manufacturing waste, along with recycled bottles and plastic car parts, is ongoing. New technologies, such as regenerative braking, which converts momentum to electricity when the brakes are stepped on in hybrid electric vehicles, also increase energy efficiency. Advances in engine-technology design include Compression Ignition Direct Injection engines, which result in less heat loss in gasoline burning engines and which also increase fuel efficiency.

Hybrid electric vehicles, as well as alternative fuel vehicles, use less gasoline and cut down on pollution. Flex-fuel vehicles can use gasoline, ethanol, or methanol for fuel. Bifuel vehicles have two tanks—one for gasoline and one for natural gas or propane. There were over 100,000 vehicles fueled by natural gas on the road in the United States in 2000, according to the U.S. Department of Energy.

The Effect of Supply and Demand

Improvement in energy efficiency depends on legislation and funds for research to develop the necessary technology, both of which are influenced by supply and demand. For example, fuel economy standards were first enforced in 1975 in response to the 1973 energy crisis. In 2002 Corporate Average Fuel Economy (CAFE) standards were 27.5 MPG for passenger cars and 20.7 MPG for light

trucks, including sports utility vehicles (SUVs). Due to the increasing popularity of SUVs in the United States starting in the late 1980s, the combined average MPG rating fell from 25.9 in 1987 to 24.6 in 1997. Energy efficiency in many areas increased through the late 1980s because of the shortage or threatened shortage of cheap imported oil. This was followed by a reversal or slowing of efficiency gains through the 1990s, when there were ample supplies of cheap fuel.

The Energy Star Program

One way in which individuals and business managers can increase energy efficiency is by using Energy Star products. Energy Star is a voluntary labeling program, introduced by the U.S. Environmental Protection Agency in 1992, that identifies energy-efficient products. Manufacturers must test all major appliances to meet energy-efficiency standards set by the Department of Energy. These are displayed on an EnergyGuide label that specifies how much energy the appliance uses, compares this with the energy use of similar products, and notes the approximate annual operating cost. To warrant the Energy Star certification, often displayed on the EnergyGuide label, products must meet stricter energy-efficiency guidelines, set by the EPA and the Department of Energy. For example, Energy Star homes must be at least 30 percent more energy efficient in terms of heating, cooling, and water heating than comparable homes built to the 1993 Model Energy Code.

Homeowners can save energy by using low-flow showerheads, lowering thermostat settings, turning off lights and appliances when not in use, sealing windows, installing storm windows, and insulating hot-water tanks. Walking or biking, carpooling, using public transport, and driving a hybrid electric car are ways to conserve gasoline and reduce vehicular pollution. The environmental importance of energy efficiency is highlighted in a 2001 EPA report stating that Americans, partly by choosing energy-efficient products, have reduced greenhouse-gas emissions by 38 million metric tons of carbon, which is equivalent to removing about twenty-five million cars from the road. SEE ALSO Vehicular Pollution.

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Patricia Hemminger

Enforcement

Both within the United States and other countries, enforcement by government agencies and individual private citizens is widely viewed as a crucial aspect of the implementation of environmental laws. It is critical as a legal

control on individuals and companies who violate pollution control standards and serves as a negative incentive for those who might otherwise violate the law. Moreover, enforcement is an important indicator of the seriousness with which government authorities regard environmental goals and policies.

In the largest Clean Air Act settlement in history, The Virginia Electric Power Co. agreed to spend $1.2 billion between 2003 and 2013 to install new pollution control equipment and upgrade existing controls at eight VEPCO generating plants in Virginia and West Virginia. The company, one of the largest coal-fired electric utilities in the nation, was charged with making major modifications to its facilities without installing required pollution control equipment. The settlement is expected to result in the annual elimination of 237,000 tons of sulfur dioxide and nitrogen oxides.

Enforcement Authority

Under a typical U.S. federal environmental statute, after finding a source of pollution—such as a steel mill or an electric utility—to be in violation of some pollution control requirement of the statute itself, or a permit or regulation issued under it, the U.S. Environmental Protection Agency (EPA) may pursue one or more of several legal enforcement options. The EPA may (1) issue a formal written notice of violation to the owner or operator of the violating source, with a copy to the state in which it is located; (2) issue an administrative order requiring the source to comply with applicable pollution control requirements; (3) make an administrative penalty assessment; (4) bring a civil lawsuit in U.S. District Court, seeking civil penalties and/or compliance with Clean Air Act requirements; and (5) request that the U.S. Department of Justice commence criminal prosecution of the polluter. Potential civil penalties may be as high as $25,000 per day of violation in some cases; criminal violators of pollution control laws may be imprisoned as well as required to pay significant criminal fines.

Most U.S. environmental laws allow enforcement of pollution control standards by state government officials and private citizens as well as federal officials. Beginning in the early 1980s, EPA ceded an increasing amount of enforcement responsibility to individual states, while retaining oversight authority. State environmental laws often are similar to federal statutes with respect to the legal options open to enforcement officials. The attitudes and capabilities of state officials in the United States vary. Some states put a higher value on traditional environmental enforcement activities than other states; some states have larger environmental enforcement staffs, and more and better enforcement resources than other states.

Many U.S. environmental laws also authorize citizen suits, lawsuits brought by any citizen against another party thought to be in violation of a pollution control standard. These citizen suits are generally barred, however, if federal or state authorities are "diligently prosecuting" an action against the same defendant for the same violation. In addition, citizen suits must be pursued with respect to environmental infractions that are "ongoing," as opposed to violations of pollution laws that occurred in the past.

Outside of the United States, the authority to enforce pollution control standards is often widely disbursed among different levels of government authorities. In Argentina, for example, environmental enforcement power is divided among federal, provincial, and municipal officials, depending on the type and extent of the pollution involved and the regulations that govern it. In Australia the responsibility for enforcing environmental laws is within the (sometimes overlapping) jurisdiction of a number of government ministries at both the state and commonwealth level. Very few nations, however, have followed the example of the United States in permitting citizen enforcement of domestic environmental standards as a supplement to the government's enforcement efforts.

Investigation, Case Development, and Litigation

At the EPA, and in many U.S. states, enforcement cases typically go through three phases: inspection and information-gathering, administrative case

> Most environmental enforcement results in monetary settlements. But not all. An executive of a New Jersey electroplating company was sentenced to twelve years in prison after he pleaded guilty to abandoning vats of sludge containing cyanide, arsenic, chromium, and other toxic materials. The cleanup at the Meadowlands Plating and Finishing Inc. factory cost the EPA more than half a million dollars.

development, and litigation. The agency initially gathers information about potential environmental violations from corporate records, on-site inspections by EPA personnel, and the specific complaints of citizen informants. The EPA then makes a strategic determination on how to address any violations that it has identified.

Such case-specific decisions take into account a number of factors, including the duration and seriousness of the violation, the violator's past record of compliance or noncompliance, national EPA enforcement policies, the potential deterrence value of the case, i.e., the likelihood that it will set an example for others who might be tempted to violate the law, and the enforcement resources available to the EPA and other governmental authorities. In cases that involve particularly serious violations and/or willfulness or bad faith on the defendant's part, the agency may initiate a criminal investigation, and request that the U.S. Department of Justice proceed with a criminal prosecution of the violator (i.e., a suit by the government) that may result in the imposition of criminal fines and/or the incarceration of guilty individuals.

In fact, most enforcement cases are resolved on the basis of negotiated settlements well before more costly, time-consuming courtroom proceedings start. In the event that enforcement litigation does go forward without settlement, however, the EPA is generally represented in federal court by attorneys from the Department of Justice. Similarly, most state environmental agencies are represented in state enforcement litigation by lawyers from the office of the state's Attorney General.

Deterrent Enforcement vs. Cooperative Enforcement

In the 1990s, a controversy arose regarding the most effective and appropriate approach to enforcing environmental laws in the United States. One view favors deterrent enforcement, which is based on the premise that regulated entities will comply with environmental standards when economic (and other) costs of noncompliance are greater than those of compliance. Under this approach, the task for environmental regulators is to make noncompliance penalties sufficiently high, and the probability that violations will be detected sufficiently great, that it becomes economically unfeasible for regulated business to violate pollution control standards. Environmental infractions should thus be met with sanctions (i.e., fines and other punitive measures), and governmental enforcement responses should be timely and appropriate, and have a deterrent effect.

In contrast, the cooperation-based enforcement approach advocated by others begins with the notion that most businesses are "good citizens," generally inclined to comply with environmental standards. This view holds that when regulated firms violate pollution control requirements, they should not generally be subject to enforcement sanctions. Rather, in the event of noncompliance, regulatory agencies should advise regulated parties on how to come into compliance.

Cooperation-based enforcement programs typically feature one or more of a variety of approaches. They frequently include compliance incentives that encourage regulated companies to "police themselves" by engaging in environmental audits and self-correction of violations, or by adopting cleanup measures that go above and beyond what the law requires, in exchange for enforcement forgiveness or flexibility. Cooperation-based programs may also incorporate compliance assistance efforts, in which public agencies assist

regulated firms and communities to comply with environmental laws through education and the provision of technical or financial assistance. Additionally, in limited instances, government officials rely exclusively on nonbinding, voluntary agreements under which industrial firms affirm their intention to comply with environmental legal requirements.

The debate between proponents of these two competing enforcement philosophies is ongoing. In practice, no regulatory system rigidly adheres to one enforcement model or the other. Instead, most are "hybrids," which pursue deterrent enforcement with varying levels of emphasis and enthusiasm, in combination with specialized compliance-assistance and compliance-incentive programs that do not involve enforcement penalties. SEE ALSO Arbitration; Clean Air Act; Clean Water Act; Environment Canada; Environmental Protection Agency; Laws and Regulations, International; Laws and Regulations, United States; Mediation; Toxic Substances Control Act (TSCA).

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Joel A. Mintz

Environment Canada

Canada's Department of the Environment, commonly known as Environment Canada, was founded in 1971. It was created to bring the different aspects of Canadian environmental policy, which had until then been split between several different departments, under the control of one main body. Environment Canada has primary, but not exclusive, control of implementing Canada's environmental policies (the Department of Fisheries and Oceans, for instance, still has control of fisheries protection).

Environment Canada has three main areas of responsibility:

- Weather and environmental prediction—collecting environmental data and forecasting weather, as well as researching climate change and other human environmental impacts
- Clean environment—developing pollution standards and controlling the use of toxic substances

- Nature—conserving biological diversity, primarily through parks and the protection of endangered species

Environment Canada also has responsibility for upholding Canada's end of international agreements, and working with the environmental agencies of other nations on issues of regional or global importance. The Commission for Environmental Cooperation, for example, is an organization established by the governments of Canada, Mexico, and the United States to address regional environmental concerns, help prevent potential trade and environmental conflicts, and promote the effective enforcement of environmental law.

In contrast to the U.S. Environmental Protection Agency (EPA), which has complete control over the implementation of American environmental legislation, Environmental Canada shares its responsibilities with the provincial governments. However, the distinction between what falls under federal authority and what belongs to the provinces is rarely clear, especially when it comes to environmental protection.

In an effort to minimize overlap, the Canadian federal government typically limits its involvement in environmental protection to a few key areas where its constitutional authority is clear and undisputed. Those areas include national parks, aboriginal title lands, inland and offshore fisheries, and issues of "national concern," such as toxic substances and endangered species, and are the focus of Environment Canada's authority. Otherwise, environmental protection responsibilities such as assessments, inspections, and enforcement generally fall to the provinces. SEE ALSO U.S. ENVIRONMENTAL PROTECTION AGENCY.

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Burkhard Mausberg

Environment Mexico ***See Mexican Secretariat for Natural Resources***

Environmental Crime

Environmental crime is a relatively new concept in U.S. and international law; thus, it is still being defined. In a general sense, an environmental crime is any violation of an environmental regulation for which criminal liability may be imposed. Almost all of the major environmental regulations in the United States contain provisions that establish criminal liability under certain circumstances, and most of these liability provisions are mirrored in state statutes. Criminal enforcement of environmental regulations is currently used in only the most egregious of cases, where the actual or potential damages are excessive or where the violator is a repeat offender. Although criminal enforcement actions are mainly taken to deter future misconduct by the individuals charged, their greater impact may be to deter those who are contemplating similar offenses.

Environmental crimes can be perpetrated at any legal level. They may arise out of violations of international, federal, or state laws. Prosecutors can bring charges for such violations at each of these levels. In international cases, U.S. attorneys prosecute violations of federal laws drawn from treaty

EXAMPLES OF ENVIRONMENTAL CRIMES

Statutes	Violations	Fines	Imprisonment
Resource Conservation and Recovery Act (RCRA)[1]	(RCRA) Taking part in any portion of the hazardous waste disposal process, including transporting, storing, and disposing of hazardous waste without a permit. (subcategory) "Knowing endangerment"[1]	(RCRA) up to $50,000 per day (subcategory) up to $250,000 per day	(RCRA) up to 5 years (subcategory) up to 15 years
Clean Water Act (CWA)[2]	(CWA) Negligent or intentional violations of the statute. (subcategory) "Knowing endangerment"	(CWA) up to $25,000 per day (subcategory) up to $250,000 per day	(CWA) up to 1 year (subcategory) up to 15 years
Clean Air Act (CAA)[3]	(CAA) Anyone who knowingly violates the statute. (subcategory) "Knowing endangerment"	(CAA) up to $250,000 per day/ $500,000 per day for corporations (subcategory) up to $1,000,000 per day for corporations	(CAA) up to 5 years (subcategory) up to 15 years

[1]"Knowing endangerment" exists when an individual "places another person in imminent danger of death or serious bodily injury.

provisions. On the local level, state or district attorneys can file charges based on state or local environmental regulations.

Environmental crimes typically involve the unauthorized disposal of hazardous material or discharge of pollutants into the air, water, or ground. In order for such activity to be deemed criminal, the government must usually be able to show that the discharge was not accidental. Most criminal laws require that a prosecutor demonstrate the defendant was aware of the activity for which the charge was filed. Because this requirement is not clearly specified in many environmental statutes, the government has had some difficulty successfully prosecuting environmental crimes. The more extreme the violation, however, the easier it becomes to prove in a court of law that the action should be considered criminal. Several environmental statutes have established a special category of criminal liability in which the "knowing endangerment" of people or the environment has occurred.

The Environmental Protection Agency (EPA) is responsible for coordinating all environmental protection actions at all levels in the United States. Although the EPA is the federal agency that most frequently investigates environmental crimes, Congress has not granted it the power to prosecute environmental crimes. Instead, after an agency official has determined that the violation of an environmental regulation is potentially criminal in nature, EPA issues a recommendation to the U.S. Department of Justice (DOJ) that charges should be filed against the violator. After investigating the case further, a U.S. attorney uses prosecutorial discretion in deciding whether or not to proceed with a criminal case. Several factors are important to the prosecutor in deciding whether the behavior should be considered criminal, including the severity of the actual or potential damages, whether intent has been shown, whether the violator was cooperative, and whether there is a history of similar violations. If the prosecutor decides to file charges, the defendant has the same constitutional rights and protections that are provided in any criminal case. SEE ALSO Environmental Justice; Environmental Regulatory Agencies; Laws and Regulations, International; Laws and Regulations, United States; Treaties and Conferences.

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Mary Elliott Rollé

Environmental Impact Statement

The U.S. National Environmental Policy Act of 1970 (NEPA) requires that all federal agencies prepare an Environmental Impact Statement (EIS) prior to making decisions that could have a significant impact on the environment. An EIS includes a description of the proposed action; alternatives to the action, including the "null" (no action) alternative; a description of the environmental context; expected impacts and irreversible use of resources; and ways to potentially lessen such impact. Impacts are broadly defined to include discussion of natural systems, human health, and the man-made environment. A draft EIS is then circulated to government agencies, in some cases Native-American tribes, and other interested parties for comment. The final EIS must include responses to any substantive comments received on the draft.

For the sake of efficiency and improved public participation, regulatory agencies frequently combine pollution-release permit review with the EIS process. Impact mitigation that is within the scope of the regulation, such as water discharges, can be required as an enforceable condition of the permit. From the outset of NEPA, courts have held that citizens and environmental groups have "standing" to challenge the adequacy of an EIS. This potential for protracted litigation provides the incentive for involving interest groups throughout the decision process. Many states and countries have adopted EIS requirements similar to those of NEPA. SEE ALSO ACTIVISM; ENVIRONMENTAL MOVEMENT; ENVIRONMENTAL PROTECTION AGENCY; INDUSTRY; LAWS AND REGULATIONS, INTERNATIONAL; LAWS AND REGULATIONS, UNITED STATES; NATIONAL ENVIRONMENTAL POLICY ACT (NEPA); PUBLIC PARTICIPATION; SYSTEMS THEORY.

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John P. Felleman

Environmental Justice

Environmental justice is broader in scope than *environmental equity* (equal treatment and protection under statutes, regulations, and practices), emphasizing the right to a safe and healthy environment for all people, and incorporating physical, social, political, and economic under the heading of environments. It is also a less incendiary term than *environmental racism*, which can be intentional or unintentional, and suggests discrimination in

A rally before the march to Laidlaw dump in Buttonwillow, California. (Zachary Singer, Greenpeace.)

policymaking, the enforcement of laws, and targeting communities of color for disposal sites and polluting industries.

Issues central to environmental justice revolve around the siting of municipal landfills, hazardous waste facilities, and nuclear-waste dumps; manufacture and sale of hazardous products; the international distribution of toxic wastes; emissions from chemical plants; lead paint exposure and other public health risks in urban residences; and occupational hazards including pesticides on agricultural lands. In addition, environmental racism not only applies to African-Americans, but also Native Americans, Asian-Americans, Hispanic-Americans, and other people of color throughout the world.

The emergence of the environmental justice movement in the 1980s stimulated debate on the extent to which race, class, and political power have been or should become central concerns of modern environmentalism and environmental management. Movement leaders charged that mainstream environmental organizations and environmental policy demonstrated greater concern for preserving wilderness and animal habitats than protecting the homes and workplaces of humans. Some advocates disassociate themselves from environmentalism altogether, identifying instead with a heritage of broader social justice imbedded in the civil rights activities of the 1950s and 1960s.

Some observers date the environmental justice movement to *Bean* v. *Southwestern Waste Management Corp.* (1979), in which African-American residents of the Northwood Manor subdivision in Houston, Texas, filed the first class action lawsuit (later unsuccessful) challenging the siting of a waste facil-

ity in their neighborhood as a violation of civil rights. The key event was a related protest in Warren County, North Carolina, in 1982. Rev. Benjamin F. Chavis Jr., executive director of the United Church of Christ's Commission for Racial Justice (CRJ), is credited with coining the term "environmental racism." He became interested in the connection between race and pollution when residents of predominantly African-American Warren County asked the CRJ for help in preventing the siting of a PCB dump in their community. The protest did not reverse plans for the disposal site, and it resulted in the arrest of more than 500 people, including Chavis. However, this event galvanized environmental justice advocates, and a full-scale movement formed as a result.

In October 1991 a multiracial group of more than 600 advocates met in Washington, D.C., for the first National People of Color Environmental Leadership Summit. In their Principles of Environmental Justice, conference participants asserted the hope "to begin to build a national and international movement of all peoples of color to fight the destruction and taking of our lands and communities. . . ." Dramatic charges of environmental racism, and the call for a new program of environmental justice took center stage. Among the goals stated in the principles was "to secure our political, economic and cultural liberation that has been denied for over 500 years of colonization and oppression, resulting in the poisoning of our communities and land and the genocide of our peoples."

The movement found strength at the grassroots level, especially among low-income people of color who faced serious environmental threats from hazardous wastes. Its leaders are academics like sociologist Robert Bullard and social activists like Chavis. For those articulating the goals of environmental justice, grassroots resistance to environmental threats is seen as a reaction to more fundamental injustices brought on by economic and social disparities. In some instances, the critique extends to questioning the capitalist system and bias in favor of Eurocentric—or Western white—social viewpoints. On one level, efforts to characterize the environmental justice movement as having its historic roots in civil rights activism, but not in the environmental movement, grew out of a desire to maintain a unique identity for the sake of its political goals.

The Warren County incident and other cases convinced Chavis and his colleagues that a national study correlating race and toxic waste sites was in order. In 1987 the CRJ published *Toxic Wastes and Race in the United States* (1987), the first comprehensive national study of the demographic patterns associated with the location of hazardous waste sites. It stressed that the racial composition of a community was the single variable best able to predict the siting of hazardous waste facilities in a community, and added that it was "virtually impossible" that these facilities were distributed by chance. The report, especially its strong inference of deliberate targeting, strengthened the position of environmental justice advocates, but it also set off a controversy over the importance of race as the central variable in that targeting. Contradictory opinions stressed the importance of economic class instead of or in addition to race, and some questioned the extent to which the placement of toxic facilities was clearly intentional.

For environmental justice advocates, the culprit in deliberate targeting was not simply private companies, but government inaction amplified by political impotence linked to race and class. The federal executive branch,

however, became more visible in the 1990s in helping to elevate environmental justice concerns to national attention. In 1992 the U.S. Environmental Protection Agency (EPA) established the Office of Environmental Justice. Its purpose was to ensure that all citizens, especially those of color or low income, received protection under existing environmental laws. Other initiatives within the EPA soon followed, and the Department of Energy (DOE) also drafted environmental justice guidelines for consideration in compliance issues. Similar action to craft policy on the basis of environmental justice concerns was carried out in states like New York and Texas.

A 1992 EPA report supported some of the claims regarding the exposure of racial minorities to high levels of pollution, but it linked together race and class in most cases. A study conducted by the *National Law Journal* that same year questioned the EPA's environmental equity record, pointing out that in the administration of the Superfund program, disparities existed in dealing with hazardous waste cleanups in minority communities as compared with white neighborhoods.

Although President Bill Clinton signed an executive order "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" in 1994, frustrations among environmental justice advocates deepened when an official Environmental Justice Act failed to pass Congress. Furthermore, no successful lawsuits have been litigated to date. Not surprisingly, enthusiasm for government action on environmental justice issues has waned among activists, and the movement's programmatic activities have instead primarily focused on public information campaigns, media outreach, brownfield economic redevelopment pilot projects, and internal organizational changes. Debate also centers on what determines 'disproportionate burden' for the poor and people of color as stated in the EPA definition of environmental justice. Aggressive litigation against polluters or congressional support for more stringent protection have not been forthcoming.

There is little doubt that the environmental justice movement has gained the attention of federal and state governments, mainstream environmentalists, scholars, and others. Some traditional environmental groups and environmental justice activists have made attempts to form alliances or sponsor joint ventures such as an environmental consortium for minority outreach in Washington, D.C. The successful campaigns for social justice have publicized the movement's cause and continued its mission. It has drawn on traditional grassroots support to reinforce its claim of being a broad-based movement and it has questioned the will and objectives of modern environmental groups to offer a definition of environmentalism that is sufficiently broad to encompass the interests of minority groups, the poor, the disadvantaged, and the politically impotent. SEE ALSO Activism; Earth Summit; Gauley Bridge, West Virginia; Poverty; Warren County, North Carolina; Yucca Mountain.

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Martin V. Melosi

Environmental Movement

History is marked by movements that challenge the dominant political ideology in ways that cannot go unnoticed. Civil rights, women's rights—such movements are often rooted in small beginnings, the passion of few, which becomes the cause of many. Born from late-nineteenth-century concern over resource exploitation, the environmental movement has become an overarching term for the growing public interest in protecting Earth and its natural resources.

Naturalists like John Muir, in the late 1800s and early 1900s, and forester Aldo Leopold, in the 1930s and 1940s, invested their time and spirit extolling the virtues of the U.S. wilderness. Both men shared a common vision for protecting the dynamic landscape of mountains and grasslands that was a distinguishing characteristic of the United States. The ensuing battles over damming rivers and logging forests helped shape the modern environmental ethic.

A Crusade for Reform

As the nation grew, the gap between people and the natural environment was widening. The introduction of railroads, telegraphs, and stockyards, helped transform cities into major industrial centers. Populations within cities increased, as immigrants flocked to them seeking employment. The resulting noise, grit, and industrial waste compelled women in the cities to take action. In Chicago, social worker Jane Addams was prepared to do just that. Coupled with the efforts of Alice Hamilton and Mary McDowell, Hull House was formed in 1888.

The creation of Hull House helped mark what is known as the Settlement House era. Across the United States, settlement houses sought to reform communities by raising public awareness about problems to find resolutions. Working-class neighborhoods were in the most dire straits, with overcrowding and poor sanitation. Hull House was concerned with the need for solid waste and sewage management in poor working neighborhoods. To remedy this, Addams became trash inspector for her Chicago ward. Likewise, McDowell motivated people to consider reduction, and pressured industries to take responsibility for their trash and sewage disposal.

The crusade for reforming working-class neighborhoods continued as McDowell opened a new settlement house in the meat-packing section of Chicago. Between the polluted waters of the Chicago River and the fields of slaughterhouse waste, McDowell began to make a strong connection between the conditions of work and daily life. Most people working in the industrial sections of the city couldn't afford to live anywhere else. Industrial byproducts that contaminated the city's air and water were unregulated, and industries weren't compelled to address the problem. Under Teddy Roosevelt, reformers

The *Clearwater,* a sloop built to promote the antipollution cause, is sailing down the Hudson river past a junkyard on its way to the first Earth Day activities in 1970. (© Bettmann/Corbis. Reproduced by permission.)

like Addams were drawn to the Progressive Party. Joining the political ranks, reformers provided greater visibility to the problems of pollution and social injustice. Consequently, leagues representing women and consumer interests gained popularity. In the 1920s the National Consumer's League exposed the use of dangerous chemicals in the watch industry, and the Gauley Bridge deaths put the national spotlight on the role played by industry in the health of its employees.

An Age of Abundance

At the end of World War II, the United States underwent rapid economic growth. The postwar abundance could be easily pinpointed by the mass consumption of everything from energy and detergents to plastics and pesticides. Goods were created and marketed to provide convenience, and amenities were plentiful. As Samuel Hays observed, a "greater distance between consumption and its environmental consequences increasingly depersonalized the links between the two" (Hays, p. 16). If people couldn't see an immediate environmental impact, society could ignore it.

The postwar impact on the environment was difficult to ignore. Within ten years, three major bouts of air pollution paralyzed the United States and Europe. In 1943 a thick smog trapped residents of Los Angeles in an unhealthy shroud of air pollution that came to be known as Black Monday. Five years later, in the Pennsylvania town of Donora, another deadly smog hung over the Monongahela Valley leaving six thousand people ill and twenty

dead. In perhaps the worst case of air pollution, a deadly fog descended on London in 1952, killing several thousand. Yet in spite of these and other environmental problems, the general public and policymakers remained relatively unconcerned.

What did finally awaken the public was the growth of an antinuclear movement in the early 1950s. As the United States performed aboveground testing of nuclear weapons, the implications for human life were startling. Protest efforts in neighboring Great Britain and the aftermath of Bikini Atoll created widespread fear about the risk of radioactive fallout from nuclear testing. Housewives and high school and college students mobilized against testing, and communities protested. Everyone, it seemed, had a stake in the debate.

The Power of Activism

By the time the Nuclear Test Ban Treaty between the United States and the Soviet Union was signed in 1963, citizens were learning about chemical fallout right in their own backyards. In 1962 Rachel Carson's *Silent Spring* introduced a public dialogue about the impacts of toxic chemicals, specifically DDT, on wildlife and the environment. César E. Chávez, leader of the United Farm Worker's Union, raised awareness of the diseases farmworkers suffered due to chemical exposure. Eventually farmworkers were able to use public awareness as a bargaining tool in their work contracts, calling for a national boycott on grapes.

Carson, like the reformers before her, felt an explicit need to make information accessible to the public, and many other scientists agreed. Paul Ehrlich's *Population Bomb*, published in 1968, sounded the alarm about overpopulation and the environmental damage that would inevitably result from a population too large for Earth to support. Garrett Hardin's "The Tragedy of the Commons," also published in 1968, explored the concept of the environment as a common area, subject to misuse in the absence of regulation. The proliferation of publications and community protests sent the message to state and national government that the pollution problem needed to appear on their agendas.

Environmental issues were swept up in a time of great social unrest. Marked by counterculture ethics and the tool of protest, citizen groups began to make connections between technological progress and pollution. Traditional wilderness preservation environmental groups dating back to the turn of the twentieth century, like the Sierra Club and the National Audubon Society, were now working alongside a new breed of antipollution activists. Protesters considered quality-of-life issues to be environmental issues. If the industries supporting their lifestyles were also degrading their neighborhoods, change needed to occur. Among the organic farms, counterculture communes, and underground publications, society was seeking to reestablish a connection with the environment.

The New National Agenda

If the 1960s arrived with a compelling or infamous start, it exited in the same fashion. In 1967 an oil tanker off of Great Britain ran aground, spilling 40,000 tons of oil. Attempts to contain the accident and salvage the remaining oil were useless. The tanker spilled another 77,000 tons of oil that washed

Crew of the Japanese whaling ship *Kyo Maru 1* using water cannons to disperse activists during an antiwhaling demonstration in the waters of the Antarctic Ocean, December 16, 2001. (© AFP/Corbis. Reproduced by permission.)

up onto British and French shores. Americans were assured that such a tragedy could never occur in their waters, but two years later, in 1969, the Union Oil Company's Platform A leaked over 200,000 gallons of crude oil that spread across forty miles of Pacific coastline. The beaches in Santa Barbara, California, were soaked with oil, choking thousands of birds and mammals. Less than five months later, the Cuyahoga River in Ohio caught on fire from chemical and sewage pollution. The relationship between industries, communities, and the environment was far from harmonious.

In 1969, in response to the public's demand for action after the Storm King case on the Hudson River, President Nixon signed the National Environmental Policy Act (NEPA). With NEPA, the national government was

taking a stand for the first time to integrate public concerns into the national environmental agenda. NEPA gave the national government the responsibility to help eliminate environmental destruction and seek a balance between the needs of industry and the environment. The Council on Environmental Quality was created to help advance this cause.

The 1970s are noted by many as the doomsday decade. Nixon's enactment of NEPA was a first step. Interest in environmental issues had remained strong from the debate over nuclear testing in the 1950s to the uninhibited use of DDT and the devastating effects of pollution on aquatic ecosystems. Environmental issues had been tied into larger social movements, but as the United States moved into a new decade, concern for the environment became a stand-alone issue. Urban pollution issues, both air and water, were tied into social interests/human health before gaining acknowledgement as purely environmental issues that had consequences for life other than humans. The intrinsic value of nature, with the exception of the wilderness preservation movement at the turn of the twentieth century, was not truly addressed until this time.

The Advent of Pollution Policies

The public's environmental agenda and steady pressure to create national pollution laws led U.S. Senator Gaylord Nelson to make a bold move. He had an idea for a national teach-in on environmental issues. A task force calling itself Environmental Action was formed to develop the idea. By seeking official support, avoiding confrontation, and scattering events across the United States, the committee hoped to involve the entire society. Many established environmental groups refused to participate, cautious of the activism that typified the era. Many of the older environmental organizations worked from a much more traditional standpoint—within political and social parameters. They believed the extremism of groups like EarthFirst! and Greenpeace threatened the progress they had made thus far and would alienate mainstream public support. Despite their hesitancy, the day met with great success. In the end, more than twenty million Americans participated in the nation's first Earth Day events on April 22, 1970.

Shortly after the Earth Day celebration demonstrated public concern about environmental problems, Barry Commoner, a notable scientist and professor, published *The Closing Circle: Nature, Man, and Technology.* Commoner wrote about the need for humans to return to a state of equilibrium with nature.

Citizen action groups like the Group Against Smog and Pollution (GASP) and the Campaign Against Pollution (CAP) lobbied their local governments for change. In Pittsburgh, GASP activists brought attention to pollution by selling cans of clean air and opening their own complaint department. The League of Conservation Voters published lists of top-polluting industries and rated politicians based on their environmental voting record.

The national government responded and took steps towards regaining the balance discussed by Commoner and those before him. The existing Clean Air Act and Clean Water Act were amended to better address the causes and effects of pollution, and regulatory measures were put into place. Between 1972 and 1976, several new federal acts were also passed, regulating ocean dumping, pesticides, and the transportation of waste. The pressure of

local groups, acting independently of larger mainstream groups, paid off. Several pieces of environmental legislation were passed, addressing the transportation and cleanup of chemicals and waste.

A view of earth from space. (United States National Aeronautics and Space Administration [NASA].)

Legal Support for Environmentalists

Special-tactic groups began to emerge to accommodate the transition of environmental issues onto the national agenda. One such group was the Natural Resources Defense Council (NRDC). A generous grant from the Ford Company led to the creation of the NRDC, a science-based initiative dealing with the new legal aspects of the movement. Even local citizen groups began to focus their interests. The Brookhaven Town Natural Resources Committee (BTNRC), a coalition of scientists and residents of Long Island, New York, was a leading antipollution group. Compelled to push for the litigation of chemical use, especially pesticides, they reestablished themselves as the Environmental Defense Fund (EDF). Throughout the 1970s the EDF, also with the help of Ford, gained notoriety for its success in waging the war on pollution in court.

The legal and scientific services offered by groups like the NRDC and EDF became important assets to the environmental movement during the 1970s. From 1976 to 1978, communities were finding themselves more widely exposed to pollution than they had first realized. Hazardous chemicals were being dumped in Virginia, the Hudson River was heavily contaminated with PCBs, and cows in upper Michigan were poisoned by polybrominated biphenyls (PBB). In Love Canal, New York, where many homes had been built on a chemical waste dump, Lois Gibbs worked endlessly to rectify the situation, lobbying polluters, politicians, and attorneys for support. In 1978 President Jimmy Carter declared a state of emergency. Gibbs later formed the Citizens Clearinghouse for Hazardous Wastes (CCHW), which helped other communities with toxic waste problems, while calling for greater toxics controls. Love Canal led directly to the passage of the Superfund law.

The International Movement

Europeans were struggling with their own environmental disasters. Swedish scientists had been studying the connection between common air pollutants like sulfur and nitrogen dioxides and high levels of acidity in many of their waters. Documenting an overall decline in the biological diversity of Scandinavia, the scientists hoped to capture international attention. The 1972 U.N. Conference on the Human Environment, hosted by Sweden, was the perfect place to present their findings. Air pollutants transported by precipitation and deposited across the land came to be known as acid rain. The idea that pollution did not remain a local problem but could be carried long distances alarmed the international community. By 1979 thirty-five countries signed the first international air-pollution agreement, the Geneva Convention on Long-Range Transboundary Air Pollution.

During the course of the 1970s, the face of environmentalism had shifted to civil action. Just as it seemed that environmental policies were effectively in place, the political climate was about to make a complete turn—but not before the fear of nuclear power reared its head again. In 1978 a partial meltdown at the nuclear plant in Three Mile Island, Pennsylvania, generated a ripple of fear and uncertainty throughout the public. Residents were evacuated, and radiation-contaminated water was released in the nearby Susquehanna

River. One year after the enactment of the Comprehensive Environmental Response Compensation Liability Act, also known as Superfund, a national law dealing with the cleanup of contaminated areas, the alarms sounded again. This time it was exposure to toxins in Times Beach, Missouri. Over 2,000 residents were evacuated when the roads were contaminated with oil-containing dioxin. The government spent around $40 million buying back homes from residents, and the cleanup efforts under Superfund ensued. As of 2003, the town remains vacant.

A Renewed Sense of Commitment

Environmentalists were rallying for more stringent enforcement of environmental policies, but the Reagan administration failed to express the same level of enthusiasm and support that had characterized the Nixon and Carter presidencies. Economic and political decisions that once involved environmental organizations now seemed to undermine the very spirit and intent of NEPA by sidelining environmental efforts. The membership ranks of environmental groups grew in response to these political threats, and a new environmental agenda focused on acid rain, ozone depletion, and global warming.

Without the willing support of the national government, environmental groups began to take matters into their own hands. Organizations like Greenpeace and Friends of the Earth, which had always encouraged direct action, had an ally with the radical Earth First!, which used similar tactics. Often referred to as direct-action groups, their methods embraced the prevention of nuclear testing, whaling, and logging through physical means. Their actions met with mixed reviews. Some felt that the movement had outgrown this type of action and that such efforts undermined the legislative progress that had been established. But activists felt that national legislation was being relied on too heavily to provide all the answers. Reintroducing the activism of the earlier movement seemed to be one of the few methods that educated the public about hazards of pollution and kept the debate alive.

With greater access to information, increasing numbers of antitoxics groups, and pressure from the international community, the pollution problem was not going to disappear. An incident in Bhopal, India, in 1984 prompted much debate about the need for uniform environmental standards and it brought a dire problem into the spotlight that had for years been ignored: environmental injustice. In Bhopal over 2,000 people died and nearly 250,000 others suffered lung and eye damage when a poorly maintained chemical storage tank overheated. The Union Carbide Company, which operated the plant internationally, was not abiding by the same regulations that applied to its West Virginia branch. The accident echoed eerily of the Gauley Bridge deaths in the late 1920s, when Union Carbide knowingly exposed hundreds of African-American miners to dangerous silica deposits.

The environmental movement expanded throughout the 1990s, becoming more international in its efforts. In 1992 the Earth Summit in Rio de Janeiro was attended by over 142 heads of state. Environmental organizations joined the proceedings with hopes of influencing the outcome. Five years later, organizations reconvened to assess the progress that had been made since the Earth Summit. Bound by the underlying desire to improve the environment, grassroots actions, national organizations, and legal proceedings have combined to present a positive force for change. NGOs were excluded

from the 1992 Earth Summit. A satellite conference was established instead. The result was that the NGOs drafted their own alternative plans, put together daily news on their conference and delivered it to the hotels of those attending the main conference, and essentially—not much was truly accomplished at the first Earth Summit. However, the satellite conference put NGOs on the board as the key players in the environmental movement. They were perceived as more knowledgeable and could network more easily in the absence of red tape that government parties encountered.

The movement represents an amalgamation of issues, from species protection and land conservation to pollution. It has also propelled itself by employing a variety of tactics to attract attention, from petitions and protests to publications and organizations. The prospect of danger to human life in the form of pollutants has motivated people from all classes and walks of life to engage in the movement to improve the quality of life. The ability to relate the causes of pollution back to human industry gave communities a sense of empowerment. Witnessing the perils of pollution in several different forms, the public has been moved to respond. The issue of pollution has compelled nations to consider the wider implications of their decisions and actions. It has shaped the course of the environmental movement, as the realization has grown that the environment extends beyond a county sign or a border patrol—and that the issue of pollution is about the shared responsibilities of consumers, manufacturers, and all residents of the larger, global community.

SEE ALSO Activism; Addams, Jane; Agenda 21; Antinuclear Movement; Brower, David; Carson, Rachel; Chávez, César E.; Citizen Suits; Commoner, Barry; Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Dioxin; Disasters: Chemical Accidents and Spills; Disasters: Environmental Mining Accidents; Disasters: Natural; Disasters: Nuclear Accidents; Disasters: Oil Spills; Dioxin; Donora, Pennsylvania; Earth Day; EarthFirst!; Earth Summit; Ehrlich, Paul; Environmental Racism; Gauley Bridge, West Virginia; Gibbs, Lois; Government; Green Party; Greenpeace; Hamilton, Alice; LaDuke, Winona; Nader, Ralph; National Environmental Policy Act (NEPA); National Toxics Campaign; New Left; Politics; President's Council on Environmental Quality; Progressive Movement; Property Rights Movement; Public Interest Research Groups (PIRGs); Public Participation; Public Policy Decision Making; Right to Know; Settlement House Movement; Smart Growth; Snow, John; Times Beach, Missouri; Tragedy of the Commons; Treaties and Conferences; Union of Concerned Scientists; Wise Use Movement; Zero Population Growth.

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Christine M. Whitney

Environmental Protection Agency ***See U.S. Environmental Protection Agency***

Environmental Racism

Up to the late 1960s, racism was defined as a doctrine, dogma, ideology, or set of beliefs. The central theme of this doctrine was that race determined culture. Some cultures were deemed superior to others; therefore, some races were superior and others inferior. During the 1960s the definition of racism was expanded to include the practices, attitudes, and beliefs that supported the notion of racial superiority and inferiority. Such beliefs and practices produced racial discrimination.

However, researchers argue that to limit the understanding of racism to prejudicial and discriminatory behavior misses important aspects of racism. Racism is also a system of advantages or privileges based on race. In the

American context, many of the privileges and advantages available to whites stem directly from racial discrimination directed at people of color. Therefore, racism results not only from personal ideology and behavior, but also from the personal thoughts and actions that are supported by a system of cultural messages and institutional policies and practices. Racism is thus more fully understood if one sees it as the execution of prejudice and discrimination coupled with power, privilege, and institutional support. It is aided and maintained by legal, penal, educational, religious, and business institutions, to name a few.

Environmental racism is an important concept that provided a label for some of the environmental activism occurring in minority and low-income communities. In particular, it links racism with environmental actions, experiences, and outcomes. In the broadest sense, environmental racism and its corollary, environmental discrimination, is the process whereby environmental decisions, actions, and policies result in racial discrimination or the creation of racial advantages. It arises from the interaction of three factors: (1) prejudicial belief and behavior, (2) the personal and institutional power to enact policies and actions that reflect one's own prejudices, and (3) privilege, unfair advantages over others and the ability to promote one's group over another. Thus, the term *environmental racism*, or *environmental discrimination*, is used to describe racial disparities in a range of actions and processes, including but not limited to the (1) increased likelihood of being exposed to environmental hazards; (2) disproportionate negative impacts of environmental processes; (3) disproportionate negative impacts of environmental policies, for example, the differential rate of cleanup of environmental contaminants in communities composed of different racial groups; (4) deliberate targeting and siting of noxious facilities in particular communities; (5) environmental blackmail that arises when workers are coerced or forced to choose between hazardous jobs and environmental standards; (6) segregation of ethnic minority workers in dangerous and dirty jobs; (7) lack of access to or inadequate maintenance of environmental amenities such as parks and playgrounds; and (8) inequality in environmental services such as garbage removal and transportation.

During the 1980s people of color began organizing environmental campaigns to prevent the poisoning of farm workers with pesticides; lead poisoning in inner-city children; the siting of noxious facilities—landfills, polluting industrial complexes, and incinerators—in communities like Warren County, North Carolina; Altgeld Gardens (the "toxic doughnut" on Chicago's Southside); Convent, Louisiana's "cancer alley;" and Kettleman City, California. Activists also demanded the cleanup of communities like Triana, Alabama that had been contaminated with dichlorodiphenyl trichloroethane (DDT), and the monitoring or closure of facilities like Emelle, Alabama's commercial hazardous landfill (the largest of its kind in the United States). In addition, they questioned the placement of large numbers of nuclear waste dumps on Native-American reservations. Meanwhile, activists, scholars, and policymakers began investigating the link between race and exposure to environmental hazards. Two influential studies exploring this relationship—one by the U.S. General Accounting Office (USGAO) and the other by the United Church of Christ (UCC)—found that African-Americans and other people of color were more likely to live close to hazardous waste sites and facilities than whites. The study by the UCC was particularly important because it made an explicit

connection between race and the increased likelihood of being exposed to hazardous wastes. The studies also made the issue of race and the environment more salient in communities of color.

In 1977 Sidney Howe, Director of the Human Environment Center, argued that the poor were exposed to more pollution than others, and that those creating the most pollution live in the least polluted places. He used the term *environmental justice* to describe the corrective measures needed to address this disparity. The term *environmental racism* came into popular use at a conference held at the University Michigan's School of Natural Resources in 1990. The conference, which focused on race and environmental hazards, brought together scholars and policymakers to discuss the relationship between racism and the environment. In addition, the term *environmental equity movement* was used in the late 1980s to describe the growing movement to address racial, gender, and class environmental inequalities. However, by the early 1990s the term *justice* replaced *equity* because environmental justice activists felt justice was a more inclusive term that incorporated the concepts of equality and impartiality. The movement focuses on two kinds of justice: (1) distributive justice, who bears what costs and benefits, and (2) corrective justice, concerned with the way individuals are treated during a social transaction. The environmental justice movement is concerned with distributive justice especially as it relates to identifying past racial injustices and advantages as well as the quest for future remedies. The movement is also concerned with corrective justice as it relates to corporate-worker–community relations and government–local community interactions. SEE ALSO ENVIRONMENTAL JUSTICE.

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Dorceta E. Taylor

Environmental Regulatory Agencies *See Environment Canada; Mexican Secretariat for Natural Resources; U.S. Environmental Protection Agency*

EPA *See U.S. Environmental Protection Agency*

Ethics

The term *environmental ethics* applies to the study of the moral foundation of our relationship with the environment. Questions posed by environmental ethics are varied, but all deal with our responsibility to the environment—what is our responsibility and how far does it go? Possibly the most basic discussion in environmental ethics begins with examining the value of nature—does nature have value on its own (intrinsic value), or is the environment only valuable to the extent that it benefits humans (instrumental value)? The answers to this question dictate how different people approach issues of conservation and pollution.

Two opposing approaches to environmental ethics became evident as the field emerged. The approach that sees the environment only in terms of what in the environment can benefit humans is called the anthropocentric approach. The nonanthropocentric approach, conversely, considers the intrinsic value in every part of the environment, from the oceans to bacteria. But there are many variations in both of these main approaches, as each seeks to expand or limit its scope for reasons of practicality and common sense. For instance, as J. Baird Callicott points out, a strictly anthropocentric view holds that humans alone are morally valuable because only they possess the property of rationalism, and they are the only inhabitants of the environment that do. However, if we follow the logic of such a point of view, infants, for example, would have no moral value and thus not merit our consideration or protection. Anthropocentrism must therefore "lower the bar" of moral consideration such that it includes groups like the one just cited.

On the other hand, an ecocentric approach that requires us to give moral consideration to every living thing on the planet would be too broad to be of any practical value, since inevitably certain human requirements will come into conflict with some parts of the environment. If mosquitoes carry diseases that kill humans (malaria, for instance), it is not practical nor would it be acceptable to claim that we should not try to eradicate the disease-carrying mosquitoes, because they deserve the same moral consideration as humans.

It is interesting to note that there are times when both approaches would arrive at the same conclusion regarding the moral justification (or lack thereof) for a certain action on the environment. In light of what we now know about dichlorodiphenyl trichloroethane (DDT), its use would be wrong from an ecocentric point of view because it causes massive damage to many different species. From an anthropocentric point of view, the damage that DDT contamination causes in humans, both physically and through destruction of the beneficial parts of their environment, would make its use unjustified.

Nonetheless, DDT, although it is banned in developed countries, was still being manufactured by China and Mexico, as late as 1999, and exported

> "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."
>
> —Aldo Leopold, *The Land Ethic,* (1949)

to developing countries. It is mainly used to control malaria, for which scientists claim there is no economically feasible alternative, and was formerly employed to protect crops imported by the United States (though this has not been the case since 1986). Is the use of DDT to control malaria justified, in the absence of feasible alternatives? What about the protection of crops? For people living in poverty, healthy crops that can be exported mean a better life—a desirable outcome. But the environmental damage to the region that is sprayed, including its human population, is as bad as it has always been. Furthermore, importing sprayed crops reintroduces DDT into our environment. Even the anthropocentric views that strictly consider human benefits vs. risks would agree that the latter use of DDT is morally unjustified, but can the same be said about its use to control malaria? Approximately one million people die each year as a result of this disease. The problem here is not scientific—alternative control methods exist. Therefore, it seems that the only morally justified action would be to make the alternative available at a reasonable price, so that neither the environment nor the people who survive the malaria suffer the consequences of exposure to DDT.

As environmental ethics matured and expanded, so did the questions it raised. Who is responsible for the cost of cleaning up hazardous waste? Or for the harm an old dump site caused when the chemicals there leaked? What if at the time the site was created, the company dumping wastes at that location only suspected this action would present a problem in the future, but had no concrete evidence of this? A holistic view (neither anthropocentric nor ecocentric) would say that the morally correct course of action would be to err on the side of caution. The *precautionary principle*, as it is known, places the burden of proof on the entity trying to promote the action it says would be beneficial—for example, the DDT manufacturer—since an action cannot be reversed once it is taken. At that point, one can only control the damage, if it occurs. Another area environmental ethics expanded into is *distributive justice*, which calls for everyone involved in a process or decision to receive their due consideration. Distributive justice is important in siting a hazardous waste disposal site, for instance. Currently, these sites often end up in low-income or politically powerless areas, where the local population has no adequate representation. Distributive justice seeks to remedy this kind of discrimination.

Environmental ethics became the basis for many political movements with sometimes contradictory ideas, but the many successful campaigns associated with such movements improved our lives by protecting the environment and reducing pollution. However, in light of the fact that the overall global picture is not improving where the environment is concerned, it would appear beneficial to all of us to adopt personal environmental ethics and live by them day to day. SEE ALSO CARSON, RACHEL; COMMONER, BARRY; DDT (DICHLORODIPHENYL TRICHLOROETHANE); EARTH DAY; EARTH SUMMIT; ECONOMICS; PRECAUTIONARY PRINCIPLE; TRAGEDY OF THE COMMONS.

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Adi R. Ferrara

FDA *See U.S. Food and Drug Administration*

F

Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is the principal governmental statute that regulates the use of pesticides to destroy, mitigate, or repel insects, pathogens, weeds, rodents, and other pest organisms. It licenses the use of these pesticides for intentional release into the environment. The law, first enacted in 1947 and amended in 1959 and 1961, requires that chemical pesticides be registered before they can be sold or distributed in interstate commerce. The rules were amended further in 1964, partially in response to Rachel Carson's *Silent Spring*, to cover a variety of potentially harmful environmental effects, such as improved labeling of products with precautionary information. In 1972, 1978, and 1998, additional modifications of the act mandated the provision of data by the manufacturers on all potential health and environmental impacts of the chemicals.

When it appears that a pesticide may cause unreasonable environmental risks, a review process is initiated to consider general ecotoxicological and environmental testing data, at various tiers or ecological **trophic** levels, on the environmental effects and fate of the pesticide. This review includes a risk assessment study to determine whether the continued use of a pesticide presents unreasonable environmental risks. The onus is on the manufacturer to demonstrate that the contested product can be used in regulated ways, with no unreasonable adverse environmental effects, or all or some registered uses may be withdrawn. SEE ALSO CARSON, RACHEL; LAWS AND REGULATIONS, UNITED STATES; PESTICIDES.

trophic related to feeding

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Clive A. Edwards

Fertilizers *See Agriculture*

Filtration *See Water Treatment*

Fish Kills

When a number of dead fish are found in one place, the incident is referred to as a fish kill, and there is significant reason to suspect pollution. The three main causes of fish kills are poisoning, disease, and suffocation.

Sanitation worker using a rake to remove dead fish from the Rodrigo de Freitas lake in Rio de Janeiro, Brazil. (©Reuters New Media Inc./Corbis. Reproduced by permission.)

Poisoning

Fish may be poisoned by a wide range of polluting substances, including pesticides, acids, ammonia, phenols, cresols, compounds of metals, detergents, or cyanides. Many of these substances are used in industrial processes or in agriculture and are released through drains or are accidentally spilled into waterways. Acid rain, derived from industrial pollutants in the atmosphere, causes rivers to become toxic for various kinds of fish. Some types of toxic algal blooms kill fish. During the 1990s the dinoflagellate *Pfeisteria piscicida* caused fish kills, ranging from a few hundred to a million fish at one time, in estuaries of the southeastern United States.

Disease

aquaculture practice of growing marine plants and raising marine animals for food

In natural environments, disease alone does not usually result in mass mortality, but under the artificial conditions of a hatchery or an **aquaculture**

operation, disease can spread rapidly and cause a fish kill. The disease may be caused by viral infections, bacteria, fungi, or internal or external parasites.

In these same natural environments, it is more common for fish to be weakened by disease and then killed en masse by some stressful environmental situation, such as low-oxygen concentration, temperature extremes, or pollution. When fish move from cold water into much warmer water such as a heated **effluent** from a generating station, bubbles may form in their tissues and they die from gas bubble disease.

effluent discharge, typically wastewater—treated or untreated—that flows out of a treatment plant, sewer, or industrial outfall; generally refers to wastes discharged into surface waters

Suffocation

Suffocation occurs when the oxygen concentration in the water falls below the level at which fish can survive. A common cause is eutrophication, which is the artificial stimulation of plant growth by pollution with fertilizers, sewage, or atmospheric fallout. When the excess plant growth decays, it lowers the oxygen concentration. The discharge of dead organic matter into a watercourse from a sewer or from an industrial operation has the same effect. The accidental spilling of a herbicide into a lake or stream may kill large quantities of aquatic vegetation, causing low-oxygen conditions.

Nuisance algal blooms may also cause suffocation. In 1994 in St. Helena Bay, South Africa, a large bloom of toxic and nontoxic algae formed in an estuary and extended into the open sea more than thirty kilometers out from the shore. The bloom sank and decomposed, forming an area with almost no oxygen and with lethal levels of hydrogen sulfide. Approximately fifteen hundred tons of dead fish and sixty tons of dead rock lobsters were washed ashore.

Many fish kills could be prevented by reducing the amount of pollution, especially nitrogen and phosphorus, entering waterways. Applications of fertilizers should be matched to the needs of the crop, sewage effluent should receive advanced treatment, and atmospheric emissions from industry and transport should be carefully controlled at source. SEE ALSO ACID RAIN; AGRICULTURE; HYPOXIA; OXYGEN DEMAND, BIOCHEMICAL; PHOSPHATES; THERMAL POLLUTION; WATER POLLUTION; WATER POLLUTION: MARINE.

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Kenneth H. Mann

Fossil Fuels

Coal, petroleum, and natural gas are referred to as fossil fuels. Their common origin is as living matter, plants, and, in particular, microorganisms that have accumulated in large quantities under favorable conditions during the earth's long history. They have been preserved (fossilized) through burial under younger sediments, to great depths and over many millions of years. The "organic" elements hydrogen (H) and carbon (C) are the primary source

of their heat content (hence the derivation of the word *hydrocarbons*). Coal has a relatively high carbon content; petroleum and natural gas have much higher hydrogen contents. The burning of fossil fuels releases large quantities of the powerful greenhouse gas carbon dioxide (CO_2) into the atmosphere, where it remains for a long time and contributes to global warming.

Fossil fuels have powered the industrialization of the world for several centuries. During the nineteenth and early twentieth centuries, coal was the primary source of energy. Then, after World War I, petroleum and later natural gas became increasingly important and together they contribute approximately 62 percent of the primary energy sources in the United States. Coal nevertheless still provides about 23 percent, mostly by conversion into electricity at large power plants. SEE ALSO COAL; ELECTRIC POWER; ENERGY; PETROLEUM.

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Heinz H. Damberger

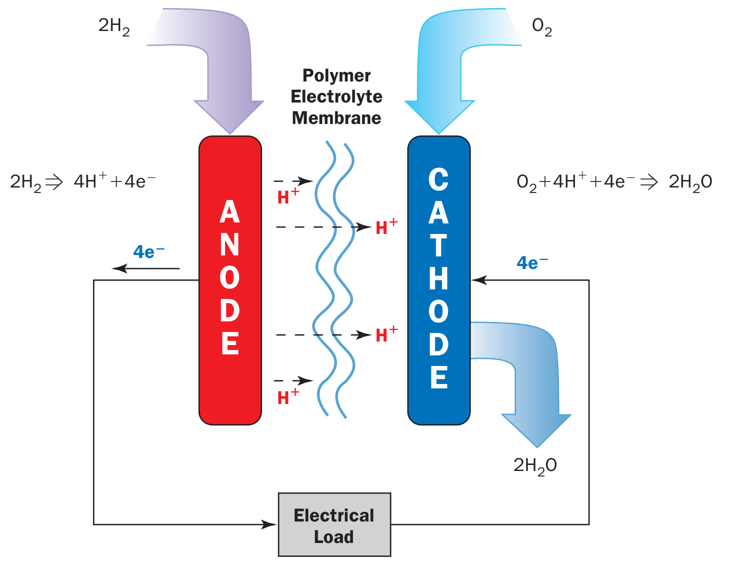
Fuel Cell

Fuel cells convert chemical energy to electrical energy by combining hydrogen from fuel with oxygen from the air. Hydrogen fuel can be supplied in two ways—either directly as pure hydrogen gas or through a "fuel reformer" that converts hydrocarbon fuels such as methanol, natural gas, or gasoline into hydrogen-rich gas. A fuel cell's only emission is water.

Fuel cells have been used in the space program since the early 1960s and are currently used in approximately six hundred office buildings, industrial facilities, and hospitals in the United States. Most automobile makers are experimenting with fuel cell–powered vehicles. DaimlerChrysler and United Parcel Service are testing fuel cell–powered delivery vans and fuel cell–powered city buses are being tested in Washington, DC. In his 2003 State of the Union, President George W. Bush proposed spending $1.2 billion to fund fuel cell research.

All fuel cells contain two electrodes—one positively and one negatively charged—with a substance that conducts electricity (electrolyte) sandwiched between them. Fuel cells can achieve 40- to 70-percent efficiency, which is substantially greater than the 30-percent efficiency of the most efficient internal combustion engines. Differences in size, weight, cost, and operating temperature all affect potential uses and, for a variety of reasons, a number of fuel cell technologies are not practical for transportation. The Proton Exchange Membrane (PEM) fuel cell is the focus of vehicle-power research. The following are the major different types of fuel cells:

- Proton exchange membrane (PEM—sometimes also called "polymer electrolyte membrane"): Considered the leading fuel cell type for passenger car application; operates at relatively low temperatures and has a high power density.
- Phosphoric acid: The most commercially developed fuel cell; generates electricity at more than 40-percent efficiency.



All fuel cells contain two electrodes–one positively and one negatively charged–with a substance that conducts electricity (electrolyte) sandwiched between them.

- Molten carbonate: Promises high fuel-to-electricity efficiencies and the ability to utilize coal-based fuels.
- Solid oxide: Can reach 60-percent power-generating efficiencies and be employed for large, high powered applications such as industrial generating stations.
- Alkaline: Used extensively by the space program; can achieve 70-percent power-generating efficiencies, but is considered too costly for transportation applications.
- Direct methanol: Expected efficiencies of 40 percent with low operating temperatures; able to use hydrogen from methanol without a reformer. (A reformer is a device that produces hydrogen from another fuel like natural gas, methanol, or gasoline for use in a fuel cell.)
- Regenerative: Currently being researched by the National Aeronautics and Space Administration (NASA); closed loop form of power generation that uses solar energy to separate water into hydrogen and oxygen.

The main difficulties in employing fuel cells on a large scale are the source and storage of hydrogen and conversion from a gasoline to a hydrogen refueling infrastructure. Ideally, hydrogen can be obtained by breaking down water with solar electrical power to produce hydrogen and oxygen. Major U.S. oil companies are already extracting hydrogen from gasoline for industrial uses and natural gas can be reacted with steam to form hydrogen in a process known as steam reforming. However both methods also produce carbon dioxide, a greenhouse gas. To power vehicles over reasonable distances hydrogen gas must be stored at extremely high pressures or as a liquid at very low temperatures. Researchers are looking at ways to store hydrogen in solids, such as super porous nanotech materials that soak up hydrogen like a sponge. It can also be extracted from methane, natural gas or gasoline by a fuel processor that reduces efficiency and does emit some pollutants.

Patricia Hemminger

Fuel Economy

The fuel economy of an automobile, measured in miles per gallon (MPG), is the distance it can move using one gallon of fuel. In 1975, in the midst of concerns about oil consumption, the U.S. Congress passed a law establishing the Corporate Average Fuel Economy (CAFE) standards, which required an increase in the fuel economy of all new cars and light trucks starting in 1978. The law required that each manufacturer meet the same standard but that a manufacturer's cars and trucks be treated differently since trucks were primarily used for work at the time. It mandated an average fuel efficiency of 27.5 MPG for cars by 1985, roughly doubling car fuel economy over ten years. The car standard remains the same as of 2003. The law also directed the Department of Transportation (DOT) to establish a standard for light trucks, defined by the DOT to include sport utility vehicles (SUVs), minivans, and pickups. The DOT established a fuel economy standard of 20.5 MPG for light trucks by 1987, an increase of about 50 percent. Small changes in light truck standards were made thereafter, with the standard increasing to 20.7 by 1996 and then, in 2003, being set to increase to 22.2 MPG by 2007.

This government-driven improvement in fuel economy has helped to limit the increase in fuel use by the United States to 30 percent over the last twenty-five years, despite the fact that vehicle miles traveled have nearly doubled over that time. In 2000 the increased fuel economy of the U.S. car and truck fleet resulted in a savings of more than forty billion gallons of gasoline, representing a 25 percent reduction compared to what the demand would have been if fuel economy had not increased. This amounts to a savings of more than 430 million metric tons of carbon dioxide, the heat-trapping gasses that cause global warming.

Vehicle travel over the coming decades is projected to rise at nearly unprecedented rates, and fuel economy is not expected to improve sufficiently to compensate for this trend. Due mostly to the explosion in sales of SUVs and other light trucks for passenger travel, the average fuel economy of a new vehicle sold in the United States has actually been declining since 1987 and by 2002 was at a two-decade low of less than twenty-four MPG.

Many factors contribute to a vehicle's fuel economy, including aerodynamics, weight, tire inflation, and engine efficiency. Simple steps that can be taken by drivers, such as properly inflating and rotating tires and keeping engines properly tuned, can improve a vehicle's MPG. Conventional technology improvements, such as continuously variable transmission systems and the use of high-strength steel and aluminum, can also make a vehicle go farther on a gallon of gas, as can advanced engine technologies such as low-friction, **variable vale control** engines. These and other conventional technologies can increase fuel economy by 40 to 70 percent.

variable vale control a system for automatically adjusting engine valve timing for better fuel efficiency

Even larger improvements in fuel economy can be achieved by combining conventional technology improvements with hybrid electric technology. Hybrid electric vehicles obtain driving power from both a gasoline or diesel engine and an electric motor/battery system. When combined with conventional technology improvements, hybrids can achieve more than a doubling of today's car and truck fuel economy. As of 2003 every major automaker had either put into production or announced the planned production of at least one hybrid car or truck in small volumes.

The issue of fuel economy is a controversial one, and is directly linked to the economic and environmental costs of U.S. passenger vehicle travel. In 2000, American drivers consumed over 120 billion gallons of gasoline at a total cost of more than $185 billion, and passenger vehicles accounted for 40 percent of the oil products that the nation consumed. Cars and trucks are also the largest single source of smog-forming air pollution in most urban areas. Most of this pollution comes from a vehicle's tailpipe, but emissions from fuel production and delivery, so-called "upstream emissions," are also a problem.

Also involved in the debate over fuel economy standards is global warming. The production, transportation, and use of gasoline for cars and light trucks in 2000 resulted in over one-fifth of the U.S. emission of the heat-trapping gases that scientists say are contributing to global warming. In the year 2000, U.S. cars and trucks emitted more of the heat trapping gasses that cause global warming than the individual emissions from every country other than the U.S., China, Russia, and Japan from all sources combined.

Supporters of increased fuel-economy standards say that if the mileage performance of the U.S. fleet of light trucks and cars was improved, it would help reduce the cost to drivers at the gas pump, the economic and military risks resulting from our nation's reliance on foreign oil, changes to the global climate, and would improve consumer choice. Those opposed to significant increases in fuel economy say that the auto industry could not economically withstand the cost of technology improvements to their fleets, consumers are not interested in better fuel economy and consumer choice would be reduced, and that better alternatives exist, such as increasing gasoline taxes. Both sides of the debate also raise opposing perspectives on the safety impacts of changes to fuel economy standards. SEE ALSO Energy Efficiency; Vehicular Pollution.

David Friedman

Furan *See Dioxin*

Gauley Bridge, West Virginia

G

Gauley Bridge, West Virginia, was the scene of a landmark case of environmental racism—one involving a conflict between the powerful and the powerless, between African-Americans and whites in 1930 to 1931. A contracting company, Rinehart and Dennis, recruited nonunion workers from the Deep South to drill the three-mile Hawk's Nest Tunnel through Gauley Mountain. The tunnel diverts the New River through giant turbines owned by Union Carbide to power Electro-Metallurgical Company, a producer of ferrosilicon.

Gauley Mountain consists of sandstone rich in silica. African-American migrants constituted 75 percent of the fifteen hundred workers employed to drill the tunnel. Supervised by armed white foremen, workers tunneled without the protection of respirators, dust suppressors, or mine ventilators. The workers—in six-day, ten-hour shifts—lived in a life-threatening environment.

By 1933 the contractor and Union Carbide faced over five hundred lawsuits. The plaintiffs claimed exposure to the risk of acute silicosis leading to lung damage, pneumonia, and tuberculosis. Because of worker transience, the number of deaths and disabilities occurring at Gauley Bridge remains

unknown. An out-of-court settlement included the dispossession of plaintiffs' evidence. In *The Hawk's Nest Incident*, Martin Cherniak writes, "The death rate of black males nineteen and older in Fayette County from 1930 to 1935 exceeded the rate [for three similar mining counties] by 51 percent, although it was almost identical from 1928 to 1930" (p. 100). An estimated 764 workers died from silicosis.

The tragic Gauley Bridge episode led all but two states to amend worker compensation laws to include silica as a hazard that could be compensated. The struggle by people of color to avoid exposure to toxic materials, however, continues. Police arrested Washington D.C.–congressional delegate Walter Fauntroy, leaders of the Southern Christian Leadership Conference, and four hundred others in 1982. They protested North Carolina's decision to use Afton, an African-American community, as the final resting place for 3,200 cubic yards of soil contaminated by polychlorinated biphynels (PCBs). For the protestors, the decision to put the PCBs in Afton was a racially discriminatory action that they suspected to be common nationwide. SEE ALSO Air Pollution; Environmental Racism; Industry.

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Craig R. Humphrey

Geographic Information System *See GIS*

Gibbs, Lois

GRASSROOTS ENVIRONMENTAL ACTIVIST AND THE "MOTHER OF SUPERFUND"
(1951–)

Lois Gibbs is a leading activist in defending the public from the dangers of toxic waste. In 1978, she discovered that her neighborhood of Love Canal in Niagara Falls, New York, was built on top of 21,000 tons of hazardous chemical waste. Faced with the health threat to her family and community, Gibbs transformed from a shy housewife to the antipollution activist now known as the "mother of Superfund." Superfund, or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), is the federal program to clean up toxic waste sites. Her work through the Center for Health, Environment and Justice (CHEJ) helps **grassroots** organizations nationwide demand accountability from industrial polluters and the U.S. government.

grassroots individual people and small groups, in contrast to government

Love Canal was the brainchild of William T. Love, an entrepreneur who wanted to link the upper and lower Niagara River for a hydroelectric power project in the late 1800s. Halted by an economic depression, the sixty-foot-wide by three-thousand-foot-long pit became a dump site for the Niagara Falls municipality, the U.S. Army, and the Hooker Chemical Corporation. After the pit was filled to capacity and covered with topsoil, Hooker sold the land to the Niagara Falls Board of Education. A school and single-family homes were built on the site in the 1950s.

Lois Gibbs, at left. (©Wally McNamee/Corbis. Reproduced by permission.)

epilepsy seizure disorder

respiratory having to do with breathing

In 1978, after reading a *Niagara Gazette* series on local hazardous waste problems, Gibbs wondered if her son's **epilepsy**, urinary tract, and **respiratory** problems could be traced to his school's location on the former Love Canal dump site. She began petitioning for the closure of the elementary school, and gained the support of fellow concerned neighbors and friends. In the process, Gibbs learned about other health problems in the community—including liver disorders, blood disease, asthma, and urinary problems—and of residents' fears that their homes would soon be worthless, trapping them in the polluted neighborhood. In August 1978, Gibbs and two neighbors took the petition with 161 signatures to the Commissioner of the State Department of Health, who immediately closed the school and recommended that pregnant women and children living close to the school leave the area. Within a week of that meeting, President Jimmy Carter declared Love Canal a federal emergency area, or emergency declaration area (EDA), and allocated funds to relocate the 239 families living in the first two rings of homes around the school.

But another level of struggle was about to begin. In Gibbs' memoir, *Love Canal: My Story*, she relates the two-year nightmare for the neighbors remaining on the canal. The cleanup effort to drain toxins from the area only released more dangerous chemicals. As president of the Love Canal Homeowners Association, Gibbs spearheaded a fight to get the government to purchase Love Canal homes at a fair price. Dramatic events of 1980, a key election year, forced government action. The U.S. Environmental Protection

Agency (EPA) released its study showing that residents exhibited chromosomal damage and angry Love Canal residents took two EPA representatives hostage. Gibbs took the Democratic National Convention by surprise in order to appeal for mortgage assistance for the residents of Love Canal. Her tenacious work publicized the severity of the pollution problem at Love Canal that inaction by Congress and President Carter would have had a political cost. President Carter finally agreed to fund permanent relocations for all Love Canal families, and the federal Superfund program was established to clean up toxic waste sites similar to Love Canal. Superfund would serve to enforce strict polluter liability so that no company could abandon a site as Hooker attempted to do in the case of Love Canal.

After moving her family to Washington, D.C., Gibbs founded the Citizens Clearinghouse on Hazardous Waste (1981), later renamed the Center for Health, Environment, and Justice (CHEJ), an organization dedicated to helping community organizations facing toxic waste issues, especially exposure to dioxin. In 1990, Gibbs was awarded the Goldman Environmental Prize. SEE ALSO Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Superfund.

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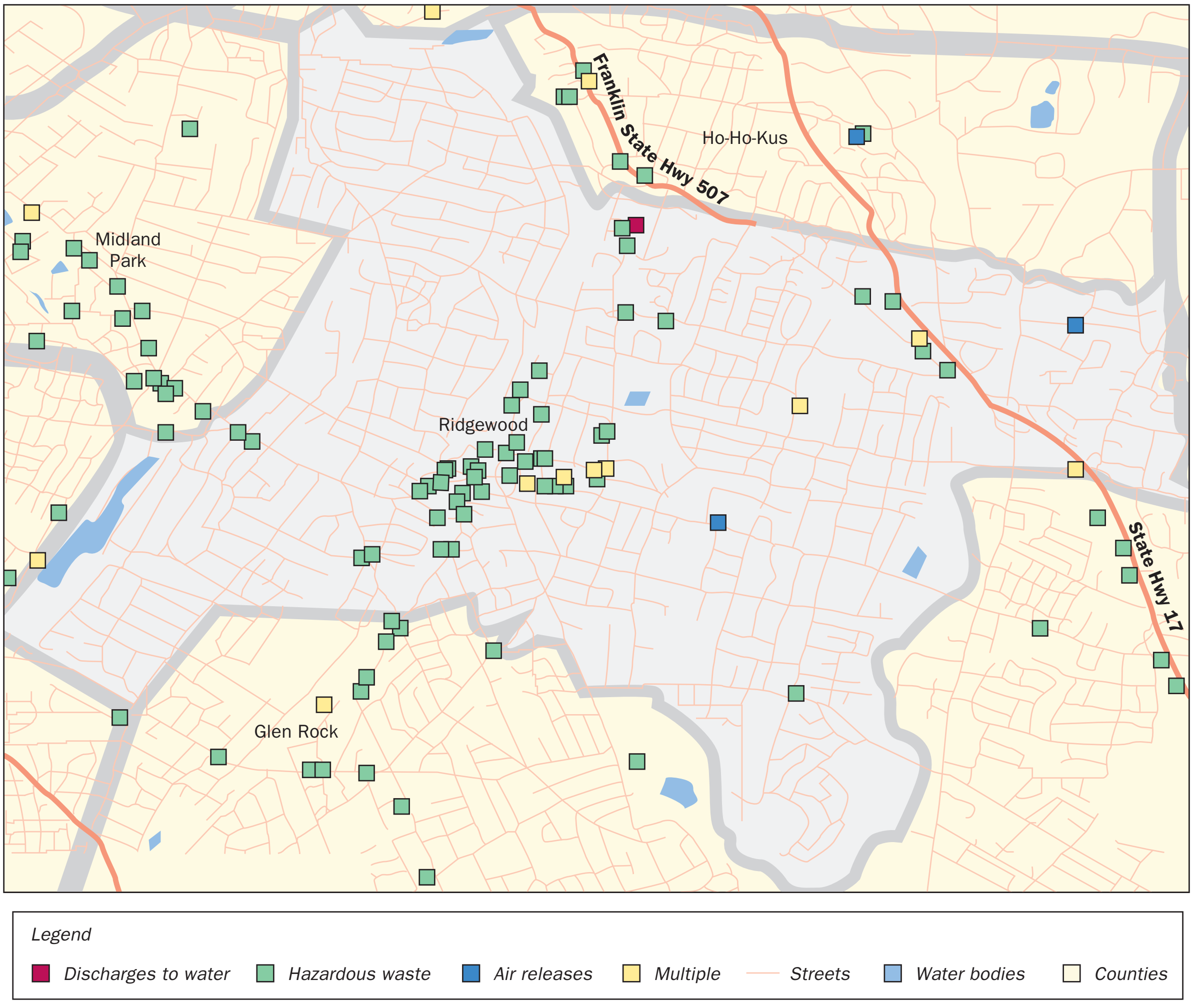
Anne Becher and Joseph Richey

GIS (Geographic Information System)

A geographic information system (GIS) is an integrated computer system that allows the storage, mapping, manipulation, and analysis of geographic or **spatial** data. It can present many different layers of information, all of which may be turned on or off depending on the user’s needs. Several components are required for a GIS to function properly. A GIS typically consists of computer hardware, software, and the people operating the system, as well as the spatial or geographic data being manipulated.

spatial related to arrangement in space

A GIS works by storing a number of different data sets that each have geographical references. The various data for any given geographic location can then be integrated based on the user’s needs. A powerful feature of GIS is that data from different sources may be combined into the same database and integrated in order to make it useful for several purposes. The U.S. Environmental Protection Agency (EPA) makes a dynamic GIS system available on its Web site that allows one to search and integrate information from several databases to create a map of pollution sources in his or her neighborhood.



SOURCE: EPA Enviromapper.

GIS is a valuable tool that is commonly used by engineers, scientists, government officials, geographers, planners, environmental modelers, geologists, epidemiologists, and others. Professionals in these fields may use GIS on a regular basis for the analysis, mapping, and integration of geographical data. GIS incorporates geography through the review of spatial distribution, land features, and location, by referencing data such as an address, parcel identifier, or latitude/longitude. Approximately 85 to 90 percent of government agencies require the evaluation of geographic data and use of a GIS. Problems related to location, proximity, trends, and patterns are typically addressed by using a GIS. It also has modeling capabilities that allow specific scenarios and situations to be evaluated and used in decision-making processes.

Examples of GIS applications in state and local government agencies include land records management, land use planning, scientific/environmental investigations, infrastructure management, and natural resources planning and management. GIS is an extremely valuable analytical tool for professionals, providing support for decision-making processes, such as determining if a site is suitable for a future landfill, calculating the soil erosion

potential in a specific region, or determining the best location for remediation treatment systems for contaminated groundwater plumes. GIS is frequently used by environmental engineers and other professionals to produce and maintain maps for sites they may be working on, watershed analyses, hydrologic studies, and many other applications.

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Margrit von Braun and Deena Lilya

Global Warming

Global warming is the gradual rise of the earth's near-surface temperature over approximately the last hundred years. The best available scientific evidence—based on continuous satellite monitoring and data from about 2,000 meteorological stations around the world—indicates that globally averaged surface temperatures have warmed by about 0.3 to 0.6°C since the late nineteenth century. Different regions have warmed—some have even cooled—by different amounts. Generally, the Northern Hemisphere has warmed to a greater extent than the Southern Hemisphere, and mid to high latitudes have generally warmed more than the tropics.

Since the advent of satellites, it has become possible for scientists to thoroughly monitor the earth's climate on a global scale. To examine the historical climate record, however, scientists have to use earlier, sparser forms of measurement, such as long-standing temperature records and less exact "proxy" data, such as the growth of coral, tree rings, as well as information from ice cores, which contain trapped gas bubbles and dust grains representative of the climate in which they were deposited. The bubbles in these cores contain oxygen, particularly oxygen isotopes 180 to 160, which are sensitive to variations in temperature. From the ratio between these isotopes at varying ice depths scientists can reconstruct a picture of the temperature variations over time in specific locations. Greater measurement uncertainty surrounds the earlier parts of this record because of sparse coverage (especially in ocean regions). Despite this uncertainty, the balance of scientific evidence confirms that there has been a discernable warming over the last century.

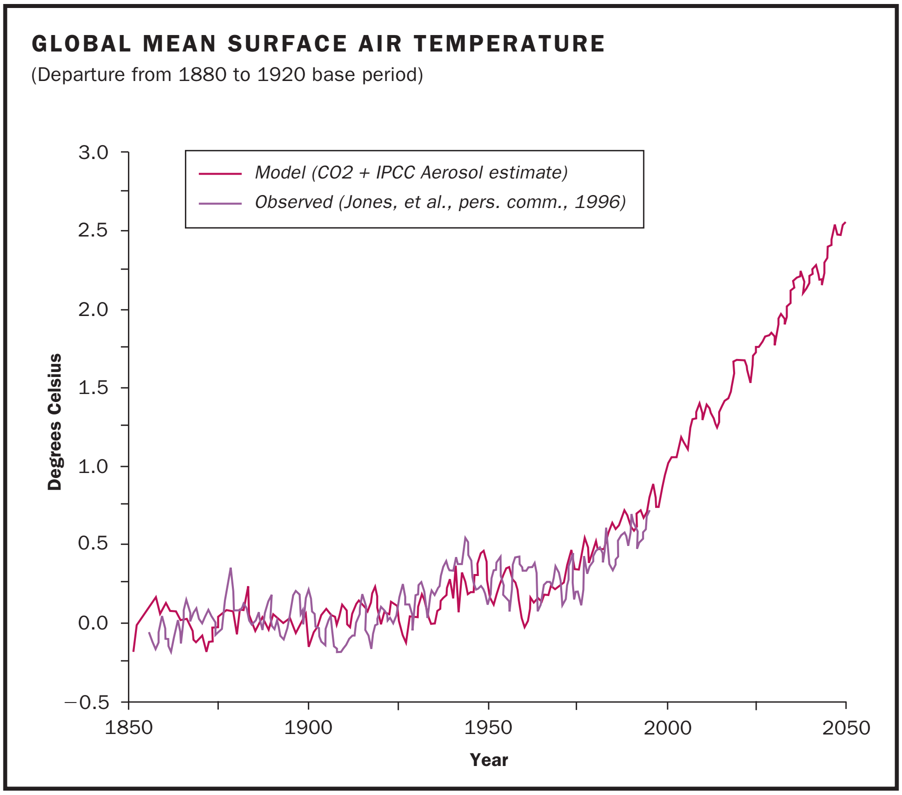
LEADING COAL-BURNING STATES FOR ELECTRIC POWER GENERATION IN THE UNITED STATES

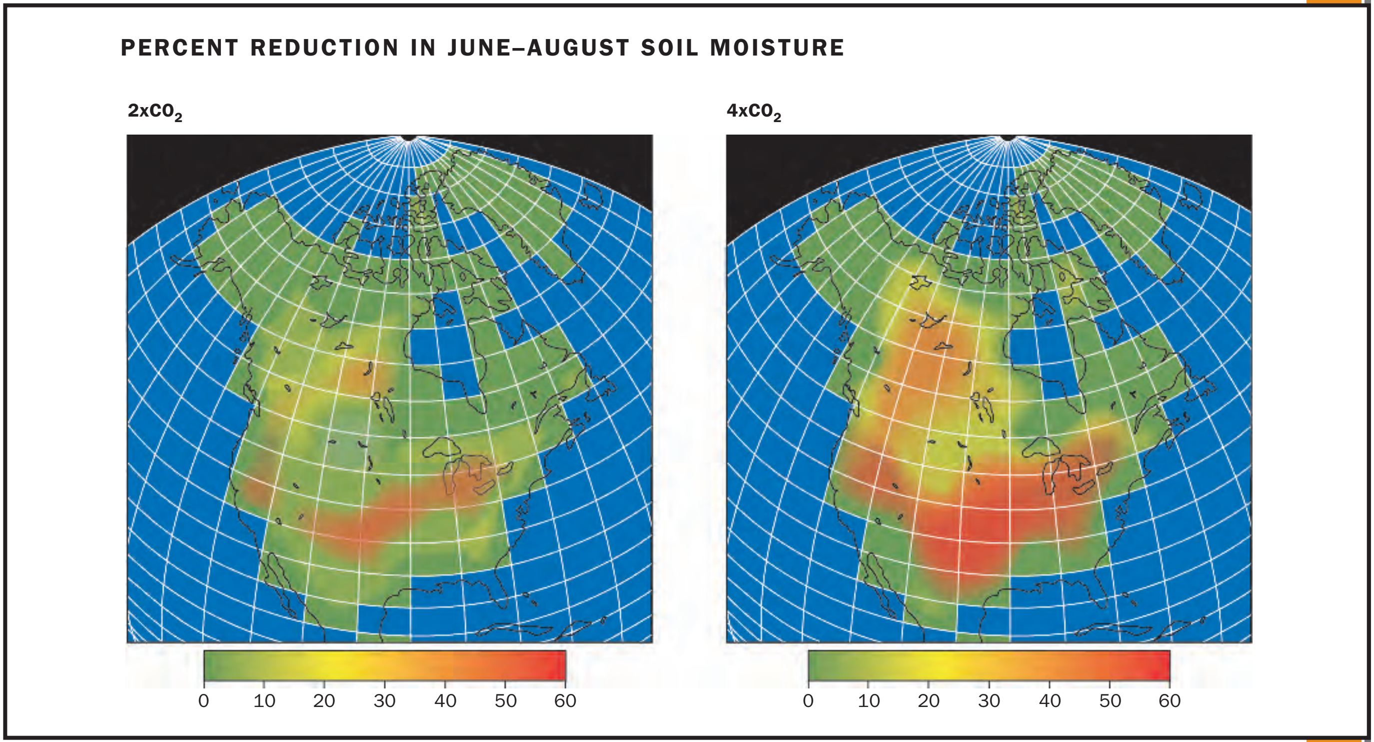
Rank	State Use	(million tons)
1	Texas	99.7
2	Indiana	59.5
3	Ohio	55.9
4	Pennsylvania	52.1
5	Illinois	46.6
6	Kentucky	40.2
7	Missouri	37.3
8	West Virginia	37.0
9	Alabama	35.6
10	Michigan	33.7
11	Georgia	33.5
12	North Carolina	29.9
13	Florida	29.9
14	Wyoming	26.5
15	Tennessee	26.1
16	North Dakota	25.1
	Other States	322.4
	Total	**990.966**

SOURCE: Adapted from U.S. Department of Energy. *Electric Power Annual 2000*, vol. 1. Available from http://www.eia.doe.gov/cneaf/electricity/epav1.

Causes

Gases such as water vapor, methane, and carbon dioxide allow short-wave radiation from the sun to pass through to the surface of the earth, but do not allow long-wave radiation reflected from the earth to travel back out into space. This naturally occurring insulation process—dubbed the greenhouse





effect—keeps the earth warm: In its absence, the earth would be about 33°C cooler than it is now. However, as the concentration of greenhouse gases increases (due largely to human activities), most scientists agree that the effect is expected to intensify, raising average global temperatures.

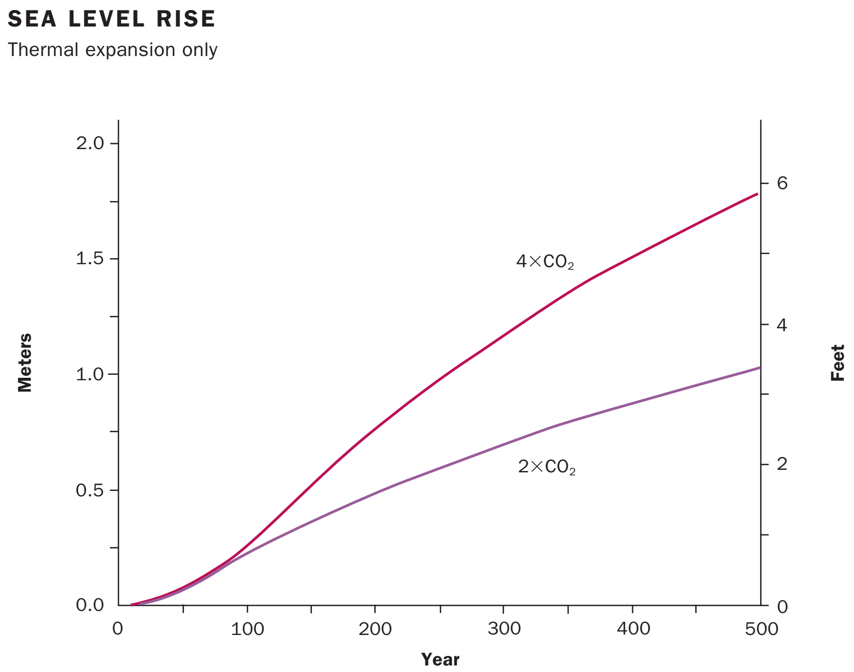
The Antarctic Larsen B shelf is breaking up, as shown in these photographs from February and March 2002, causing fears of global warming. Seen in these photographs is the loss of 500 billion tons of ice. (© Reuters NewMedia Inc./Corbis. Reproduced by permission.)

However, the earth's climate is known to vary on long timescales. The existence of naturally occurring ice ages and warm periods in the distant past demonstrates that natural factors such as solar variability, volcanic activity, and fluctuations in greenhouse gases play important roles in regulating the earth's climate. A minority of scientists believe that purely natural variations in these factors can account for the observed global warming.

Climate in the Twenty-first Century

Climate forecasts are inherently imprecise largely because of two different sorts of uncertainty: incomplete knowledge about how the system works—understandable for a system governed by processes the spatial scales of which range from the molecular to the global and uncertainty about how important climate factors will evolve in the future. A variety of factors affect temperature near the surface of the earth, including variability in solar output, volcanic activity, and dust and other aerosols, in addition to concentrations of greenhouse gases.

However, this uncertainty does not stop one from making some broad statements about (1) the likelihood of the sources of observed global warming and (2) the likely effects of continued warming. In the first case, attempts by climate modelers to reproduce the observed global near-surface temperature

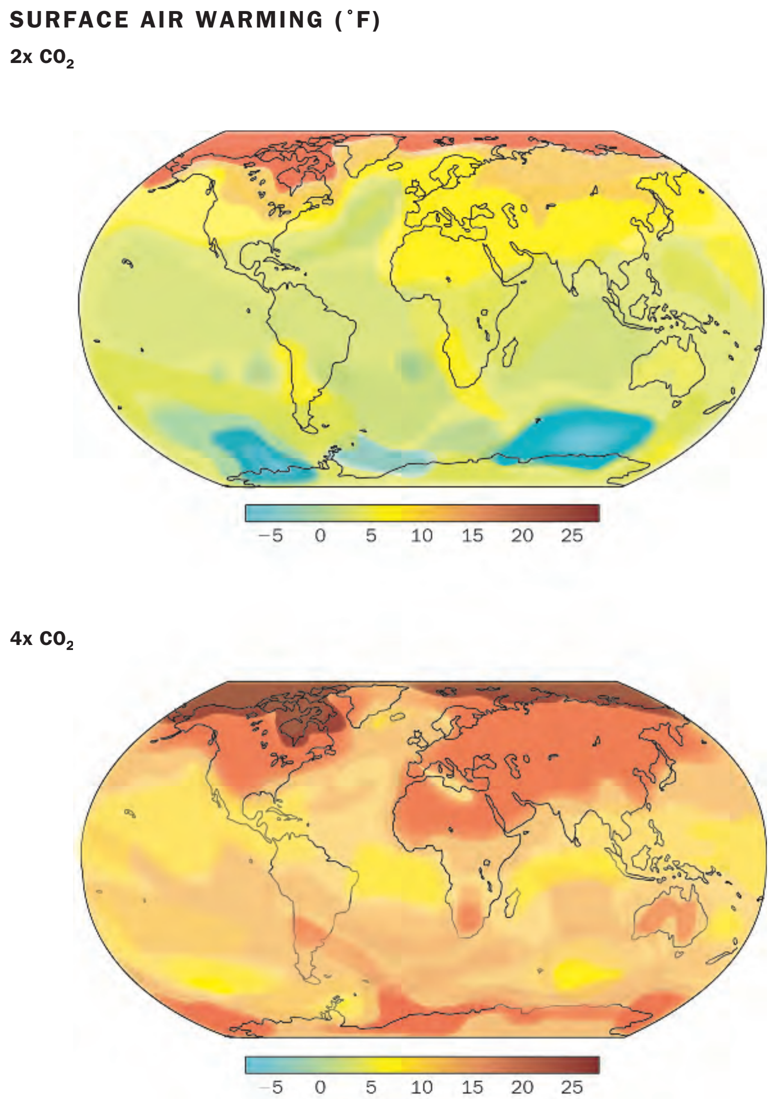


SOURCE: GFDL climate model

record using only natural variability in climate models have proved inadequate. The Third Assessment Report (2001) of the Intergovernmental Panel on Climate Change (IPCC) attributes some 80 percent of recent rises in global temperature to human activities, with other important contributions coming from volcanic and solar sources. Over the coming century, likely effects of continued warming include higher daily maximum and minimum temperatures, more hot days over most land areas, fewer frosts in winter, fewer cold days over most land areas, a reduced daily range of temperatures, more extreme precipitation events (all very likely), increased risk of drought, increases in cyclone peak wind, and precipitation intensity (likely). Other effects, such as the disintegration of Antarctic ice sheets, carry potentially enormous implications, but are considered very unlikely.

Responses to Climate Change

These effects are likely to be beneficial in some places, but disruptive in most, and as a consequence, governments around the world have begun planning responses to climate change. These fall into two categories: mitigation, which involves taking action to prevent climate change (usually by cutting greenhouse gas emissions) and adaptation, which involves adapting to the effects as and after they happen. For example, if sea levels rise in the next century due to thermal expansion of the oceans, low lying areas such as the Netherlands and Bangladesh may be flooded. A mitigation strategy would involve trying to cut emissions to forestall the heat-driven sea level rise, whereas an adaptation strategy might be to build large barriers to prevent the sea level rise from flooding these countries. In wealthy countries such as the Netherlands this is perhaps a viable option. It is not so clear that Bangladesh—one of the world's poorest countries—will be in a position to implement this sort of strategy.



SOURCE: GFDL R15 Climate Model; CO_2 transient experiments, years 401–500

Because of the potentially serious ramifications of continued global warming, the World Meteorological Organisation and United Nations Environment Programme jointly established the IPCC in 1988. It assesses scientific and socioeconomic information on climate change and related impacts, and provides advice on the options for either mitigating climate change by limiting the emissions of greenhouse gases, or adapting to expected changes through developments such as building higher flood defenses.

In the wake of the general increase in the awareness of environmental issues in the Western world since the 1970s, global warming has become an important political issue in the last decade. Following the successful implementation of the Montréal Protocol (1987) that prohibited the production of ozone-depleting gases (i.e., chlorofluorocarbons [CFCs], halons, and carbon tetrachloride) starting in 2000, the international community sought to address the problem of global warming in the Kyoto Protocol (1992). This

involves industrialized countries taking the lead on cutting greenhouse gas emissions. The protocol requires them to decrease their emissions to 90 percent of their 1990 levels. The Kyoto Protocol comes into effect if fifty-five parties to the convention ratify the protocol, with "annex 1" (or industrialized) parties accounting for 55 percent of that group's carbon dioxide emissions in 1990.

This approach has proved controversial for a variety of reasons: (1) It applies primarily to industrialized countries, freeing some of the world's worst polluters, such as China and Saudi Arabia, from having to comply; (2) the reductions are arbitrarily fixed at 10 percent of a country's 1990 level, irrespective of whether that country is a big polluter, like the United States, or a relatively small polluter, like Sweden; (3) disagreements about whether the cuts imposed by the treaty will actually be worth the economic costs; (4) the treaty targets only gross emissions rather than net emissions—during the negotiations key differences emerged between a group of nations that favored the use of man-made forests as "carbon sinks" planted to soak up carbon emissions, and countries that believed this to be an inadequate response.

Although the Kyoto Protocol has been enthusiastically backed by European countries, various wealthy countries remain outside the treaty, most notably Australia and the United States. The U.S. decision to not sign the Kyoto Protocol has proved particularly controversial, as the United States emits some 23 percent of global greenhouse emissions, while only containing 5 percent of the global population. The current Bush administration does not intend to ratify the agreement on the grounds "that the protocol is not sound policy," according to U.S. Undersecretary of State Paula Dobriansky. SEE ALSO CARBON DIOXIDE; CFCS (CHLOROFLUOROCARBONS); GREENHOUSE GASES; HALON; METHANE (CH_4); NO_x (NITROGEN OXIDES); OZONE; TREATIES AND CONFERENCES.

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David Frame

Government

Government is the set of formal institutions used by a society to organize itself; government sets rules for general conduct by citizens. These rules are usually based on customs that have evolved in that society. Most governments include formal organizations that serve *legislative*, *executive*, or *judiciary* functions. These are called branches of government. Government may also be organized into levels: national government and subordinate governments such as states or provinces, counties, and cities or towns.

FEDERAL AGENCY AREAS OF ENVIRONMENTAL RESPONSIBILITY

Federal Agency	Area of Responsibility
EPA http://www.epa.gov	Air pollution Water pollution Solid waste disposal Hazardous waste disposal Pesticides Toxic substances
Department of the Interior http://www.doi.gov	
Fish and Wildlife Service National Park Service Bureau of Land Management	Threatened and endangered species (nonmarine) Wildlife refuge management National parks management Mining on public lands
Department of Defense http://www.defenselink.mil/	
Army Corps of Engineers	Regulation of filling in waters and wetlands
Department of Commerce http://www.commerce.gov	
National Marine Fisheries Service	Threatened and endangered species (marine)
National Oceanographic and Atmospheric Administration http://www.noaa.gov	Marine mammal protection Coastal zone management
Department of Agriculture http://www.usda.gov	
National Forest Service Animal and Plant Health Inspection Service	Forest management Animal and plant health
Food and Drug Administration http://www.fda.gov	Food and drug safety
Council on Environmental Quality http://www.whitehouse.gov/ceq/	National Environmental Policy Act

SOURCE: Antista, James V.; Boardman, Dorothy Lowe; Cloud, Thomas A.; *et al.* (2001). "Federal, State, and Local Environmental Control Agencies" In *Treatise on Florida Environmental and Land Use Law*. Tallahassee, FL: The Florida Bar.

Democracy and Representation

The U.S. system of government is a representative system rather than a pure democracy. In a pure democracy, citizens decide together what actions the government should take. The New England town meeting reflects this concept most closely. Generally, the U.S. representative system, also called "republican" (after the Roman form of government), functions by agents: Relatively few citizens elected periodically by the populace at large make decisions about what the government should act on.

Politicians campaign or make decisions based on a mix of their political party's position and their constituents' needs and viewpoints. If constituents view an issue as important, they are likely to make their preferences known to their representatives. These *active attentives* are aware of issues and communicate their preferences, thus demanding that elected officials act as delegates. If an issue does not affect constituents directly, they are likely to remain quiet, allowing representatives to act as trustees and make the decision themselves.

The Development of the U.S. Government

The first U.S. government, established in 1781, was a "treaty of friendship" called *The Articles of Confederation*. This treaty among independent nation

states (the thirteen colonies) allowed each state to establish its own laws, coin its own money, and tax import goods. Jointly, each state was obliged to assist the others in defense and to pay a share of the Revolutionary War costs. Common laws were to be enacted only when state delegates to a "Congress" agreed on them unanimously. There was no president and no bureaucracy; the government engaged in no day-to-day operations.

This confederation soon proved ineffective, and in 1787 a Constitutional Convention was called to create a stronger system. This new government required each state to give up power to the national, or federal, government so it could act without requiring unanimous agreement by the individual states.

The modern U.S. government system consists of three levels of government and three branches. The three levels of government are the federal (national), state, and local governments. The federal government deals largely with international agreements, treaties, and broad public issues affecting constituents across the nation. State governments primarily govern areas that affect the well being of its citizens; some of these are national in scope. When states address issues that are national, the general rule is that they can always "do more" than the federal government, but not less. They can require cleaner air and water than federal standards, for example. Local governments (counties, cities, towns, and special districts such as school districts) are seen as service providers who make our daily life easier; these services include snowplowing, public schools, and garbage collection.

Citizens may fail to notice all that local and state governments do. Yet, decisions to plow roads have a great deal to do with protecting the water supply for both drinking and recreation, because it includes a decision to use sand or salt to create safer winter driving. And a heavy spring snowmelt, once it enters the sewage treatment system, can cause flooding, sewage backups, and create health risks. Likewise, garbage collection is just the first step in local solid waste management that can end at an incinerator or a landfill. Thus the direct delivery of services such as snowplowing and garbage collection that citizens normally see, bring into being the less visible management programs of our state and local governments.

Often, local and state governments are seen as "policy laboratories" for the federal government. When a problem reaches national attention, the federal government looks to states and local governments with existing policies for examples of what works, and uses their policy as a model for a national one. This "ratcheting effect" is particularly evident in pollution control policies during the twentieth century. Cities enacted the first clean air statutes around 1900; county and state air quality policies grew out of these local laws by the 1950s. The national Clean Air Act of 1970 was, in turn, modeled after several state policies.

The three branches of government—executive, legislature, and judiciary—serve as a system of *checks and balances* to limit the power of any one branch of government. These limits derive from separate powers (authority given to one branch to act on an issue), shared powers (where it takes two or more branches acting together to accomplish something), and checks (where one branch can stop another branch from acting).

Comparative Democratic Governments

The movement to "harmonize" legislation and open borders in Europe under the European Union (EU) is a confederated system similar to the

THREE BRANCHES OF GOVERNMENT

The Legislature

The branch of government that proposes and enacts laws. Usually comprised of one or more "chambers" or houses, whose members are usually elected, though sometimes they may be appointed. A legislature debates and decides what laws to enact. In the United States, the national legislature, the U.S. Congress, has two houses: the Senate, with a greater focus on international policy and administration of government, and the House of Representatives, with a stronger focus on domestic or internal policy and budget and taxation.

While members of most legislatures are elected by citizens to represent their interests by geographic region, this is not always true. The parliament of the United Kingdom has one house whose members are elected, the House of Commons, and a second house, the House of Lords, composed of members of the aristocracy, or peers, who inherit their seats. In the late 1990s, the parliament of the United Kingdom was reorganized, and the seats held by a number of the peers were eliminated.

The Executive

The branch of government that implements the laws and conducts the daily operations of government. In the United States, the national executive branch consists of the president and various administering bureaucracies. These bureaucracies include cabinet offices (such as the Department of Interior, Housing and Urban Development, Commerce), independent agencies (like the Environmental Protection Agency and the Central Intelligence Agency), regulatory commissions (including the Securities Exchange Commission, the Federal Elections Commission, and the Nuclear Regulatory Commission), and government corporations (the U.S. Postal Service).

The executive branch often promotes particular policies and so works to enact laws as much as it enforces and implements laws. In the United Kingdom and other **unitary systems,** lower levels of government (counties or "shires") are seen as administrative arms of the national government. In the United States, the states enact and carry out their own laws as well as being responsible for upholding federal laws.

The Judiciary

In the United States, the judiciary is the branch of government that resolves disputes. Some disputes are over facts, as in a jury trial for a criminal case between the plaintiff (government) and the defendant (one or more citizens). Civil cases are controversies between two or more citizens or a citizen and an organization. In all disputes over facts, there is some previous rule, law or policy established that specifies appropriate behavior. The disagreement over facts determines who did, or did not, violate that appropriate behavior.

Disputes also arise over questions of what the law is intended to mean. These cases, called appellate cases, are decided by a panel of judges. Usually, there are between three and nine justices who vote on the best way to interpret the law, and agreement occurs by majority vote (the U.S. Supreme Court has nine justices; lower federal and state appellate courts generally have fewer justices).

unitary system a centralized system or government

United States under the Articles of Confederation. The EU is a representative overgovernment, (i.e., a governing body that is instituted with authority to make and representatives from the existing EU nations). The EU now shares a single currency (the Euro) among these several nations and formal administrative agencies, including the European Environment Agency, something the early U.S. system lacked.

The unitary system is also a form of democratic government. It is used in the United Kingdom and other nations that have a parliamentary government. A unitary government combines the executive and legislative branches

and operates on several levels. Elected legislators choose by vote from their own group a prime minister to run the government. The lower levels of government carry out national policies, but do not make their own.

Canada is part of the British Commonwealth and has a parliamentary system that combines the executive and legislative branches. While the monarchy of the United Kingdom is also the monarchy of Canada, and appoints a governor-general to act as its representative, the governor-general is a symbol of the monarchy, rather than a political leader. Governance of Canada resides in the prime minister and the parliament. The Canadian parliament has two houses, similar to the U.S. Congress. However in Canada, the prime minister recommends and the governor-general appoints the members of the upper house, the Senate. Senators may hold office until age seventy-five. Elections are held for members of the lower house, the House of Commons. Canada is a federal system with multiple provinces, each having their own constitutions and laws. The ability to legislate over certain natural resources is a shared power between the Canadian provinces and the federal Canadian government.

The United Mexican States, the U.S. southern neighbor, shares with Canada and the United States a federal system of states and a centralized national government. But like the United States, Mexico has a presidential system with a separate executive branch. The bicameral, or two house National Congress (Congreso de la Union) consists of a Senate (Camara de Senadores) and a Federal Chamber of Deputies (Camara Federal de Diputados). As in the United States, the Senate has fewer members than the Federal Chamber of Deputies (128 to five hundred). However, in both houses the members are chosen in two ways. Some members are elected to a particular seat, while others are allocated a seat in their house of the legislature based on the proportion of a party's vote in the last election, (thirty-two seats allocated in the Senate, two hundred allocated in the Chamber of Deputies). This proportional method of allocating seats ensures that minor parties have a voice in government. While this broadens the democratic input, it can sometimes cause more conflict and gridlock.

Sharing borders with the United States, both Canada and Mexico have joined with the United States to create the North American Free Trade Agreement (NAFTA), a treaty similar to that which gave rise to the European Union. Rather than creating a new level of government over the nations, this treaty addressed commerce across borders. However, many citizens believed NAFTA caused many social problems, including environmental problems. To address public concern, the North American Agreement on Environmental Cooperation, along with other side agreements, was drafted to protect the environments of the three nations. Among the provisions of this agreement are the promotion of sustainable development within Canada, the United States, and Mexico, and to foster protection of the natural environments of these nations.

The Function of Government in Society

The role of government in a society rests on the answer to one question: Are humans essentially "good" or "bad"? A society that views humans as essentially good sees little need for government (hence, the government would be limited and inactive). A society answering essentially bad sees the need for a large and active government. Environmental issues center on this question.

Are people and corporations self-interested (or bad) and thus in need of governmental regulation? Or are people able to act for the good of society as well as themselves, requiring less regulation?

The United States has historically responded to this question with mixed answers. From the federalists (who wanted a larger, more powerful government) and antifederalists beliefs about the appropriate size and functions for government have combined with what citizens "value" for society make up a set of commonly held ethics that are referred to as the *political culture*. In the United States, multiple views or cultures exist; ours is seen as a *pluralist*. nation. These disagreements form the basis of environmental policy debates.

The government achieves its goals through different policy mechanisms. Environmental legislative policies use two primary methods: regulation that prescribes particular allowed behaviors, which are then monitored and enforced, and market incentives that offer financial incentives to obtain a desired outcome, but allow individuals and firms to decide how to achieve it.

Interactions between levels and branches of government are common. Organizations of government officials, such as mayors and governors, have been created. These act as interest groups that jointly address common problems or lobby higher levels of government for policy solutions. Transboundary pollution agreements between states evolved this way, ratcheting policy from local to state to national governments. Increasingly, such escalation has included shifting policy to the international level. Common international problems require the negotiation of treaties among often very different countries. The interests of each country therefore influence the governance of international issues. But international policies specify standards, often calling for changes in national policies, as seen in the Kyoto Protocol and the environmental side agreements of the North American Free Trade Agreement. Similarly, the United Nations Environment program Agenda 21, an outgrowth of the UN Earth Summit held in Rio de Janeiro, Brazil in 1992, is a global plan of action that influences individual national policies. Agenda 21 encompasses international efforts to promote sustainable development and provides guidance on how nations may change their own environmental policies. SEE ALSO AGENDA 21; ENVIRONMENT CANADA; LAWS AND REGULATIONS, INTERNATIONAL; LAWS AND REGULATIONS, UNITED STATES; LEGISLATIVE PROCESS; MEXICAN SECRETARIAT FOR NATURAL RESOURCES (LA SECRETARÍA DEL MEDIO AMBIENTE Y RECURSOS NATURALES); NUCLEAR REGULATORY COMMISSION (NRC); OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA); POLITICS; PRESIDENT'S COUNCIL ON ENVIRONMENTAL QUALITY; PUBLIC POLICY DECISION MAKING; RIGHT TO KNOW; TREATIES AND CONFERENCES; U.S. ENVIRONMENTAL PROTECTION AGENCY.

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Sara E. Keith

Green Chemistry

The term *green chemistry*, coined in 1991, is defined as "the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances." This approach to the protection of human health and the environment represents a significant departure from the traditional methods previously used. Although historically societies have tried to minimize exposure to chemicals, green chemistry emphasizes the design and creation of chemicals that are not hazardous to people or the environment. It has been applied to a wide range of industrial and consumer goods, including paints, dyes, fertilizers, pesticides, plastics, medicines, electronics, dry cleaning, energy generation, and water purification.

At the heart of green chemistry is the recognition that hazard is simply another property of a chemical substance. Properties of chemicals are caused by their molecular structure; they can be modified by changing that structure. The types of hazards that can be addressed by green chemistry vary. They include physical hazards (being explosive or flammable), toxicity (being carcinogenic or cancer causing, or lethal), or global hazards (climate change or stratospheric ozone depletion). Therefore, in the same way that a substance can be designed to be red or hard, it may also be designed to be nontoxic.

The Principles of Green Chemistry

Chemists and chemical engineers applying green chemistry look at the entire life cycle of a product or process, from the origins of the materials used for manufacturing to the ultimate fate of the materials after they have finished their useful life. By using such an approach, scientists have been able to reduce the impacts of harmful chemicals in the environment.

Research and development in the field of green chemistry are occurring in several different areas.

Alternative feedstocks. Historically, many of the materials used to make products often were toxic or depleted limited resources such as petroleum,

but green chemistry research is developing ways to make products from renewable and nonhazardous substances, such as plants and agricultural wastes. For example, cellulose and hemicellulose, which constitute up to eighty percent of biomass, can be broken down to sugars, then fermented to chemical commodities such as ethanol, organic acids, glycols, and aldehydes. Converting biomass to ethanol has become economically and technically viable due to a new class of genetically modified bacteria capable of breaking down the different sugars in hemicellulose.

Benign manufacturing. The methods used to make chemical materials, called synthetic methods, have often employed toxic chemicals such as cyanide or chlorine. In addition, these methods have at times generated large quantities of hazardous wastes. Green chemistry research is developing new ways to make these synthetic methods more efficient and to minimize wastes while also ensuring that the chemicals used and generated by these methods are as nonhazardous as possible. For example, a number of industries, such as the pulp and paper industry, use chlorine compounds in processes that generate toxic chlorinated organic waste. Green chemists have developed a new technology that converts wood pulp into paper using oxygen, water and polyoxometalate salts, while producing only water and carbon dioxide as by-products.

Designing safer chemicals. Once it is certain that the feedstocks and methods needed to make a substance are environmentally benign, it is important to ensure that the end product is as nontoxic as possible. By understanding what makes something harmful (the field of molecular toxicology), scientists are able to design the molecular structure so that it is not dangerous.

Green analytical chemistry. The detection, measurement, and monitoring of chemicals in the environment through analytical chemistry have long been a tool for environmental protection. Instead of measuring environmental problems after they occur, however, green chemistry seeks to prevent the formation of toxic substances and thus prevent such problems. By making sensors and other instruments part of industrial manufacturing processes, green analytical chemistry is able to detect even tiny amounts of a toxic substance and to adjust process controls to minimize or stop its formation altogether. In addition, although traditional methods of analytical chemistry employ substances such as hazardous solvents, green analytical methods are being developed to minimize the use and generation of these substances while conducting analysis.

Why Green Chemistry?

Green chemistry is effective in reducing the impact of chemicals on human health and the environment. In addition, many companies have found that it can be cheaper and even profitable to meet environmental goals. Profits derive from higher efficiency, less waste, better product quality, and reduced liability. Many environmental laws and regulations target hazardous chemicals, and following all these requirements can be complicated. But green chemistry allows companies to comply with the law in much simpler and cheaper ways. Finally, green chemistry is a fundamental science-based approach. Addressing the problem of hazard at the molecular level, it can be applied to all kinds of environmental issues.

Since 1991, there have been many advances in green chemistry, in both academic research and industrial implementation. For example, Spinosad, an insecticide manufactured by fermenting a naturally occurring soil organism, was registered by the EPA as a reduced-risk insecticide in 1997. Spinosad does not leach, bioaccumulate, volatilize, or persist in the environment and in field tests left 70 to 90 percent of beneficial insects unharmed. It has a relatively low toxicity to mammals and birds and is slightly to moderately toxic to aquatic organisms, but is toxic to bees until it dries. In another advance, an industrial cleaning solvent, ethyl lactate, made from cornstarch and soybean oil was patented in 2000 and is competitively priced with petrochemical solvents. It biodegrades to carbon dioxide and water and has no known harmful effects for the environment, humans, or wildlife. These advances, however, represent an extremely small fraction of the potential applications of green chemistry. Because the products and processes that form the basis of the economy and infrastructure are based on the design and utilization of chemicals and materials, the challenges facing this field are enormous. SEE ALSO Biodegradation; Renewable Energy.

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Paul T. Anastas

Green Marketing

Green marketing is a way to use the environmental benefits of a product or service to promote sales. Many consumers will choose products that do not damage the environment over less environmentally friendly products, even if they cost more. With green marketing, advertisers focus on environmental benefits to sell products such as biodegradable diapers, energy-efficient light bulbs, and environmentally safe detergents.

People buy billions of dollars worth of goods and services every year—many which harm the environment in how they are harvested, made, or used. Environmentalists support green marketing to encourage people to use environmentally preferable alternatives, and to offer incentives to manufacturers that develop more environmentally beneficial products.

The concept of green marketing has been around at least since the first Earth Day in 1970. But the idea did not catch on until the 1980s, when rising public interest in the environment led to a demand for more green products and services. Manufacturers responded to public interest by labeling hundreds of new products "environmentally friendly"—making claims that products were biodegradable, compostable, energy efficient, or the like.

In spite of its growing popularity, the green marketing movement faced serious setbacks in the late 1980s because many industries made false claims about their products and services. For instance, the environmental organization

CorpWatch, which issues annually a list of the top ten "greenwashing" companies, included BP Amoco for advertising its "Plug in the Sun" program, in which the company installed solar panels in two hundred gas stations, while continuing to aggressively lobby to drill for oil in the Arctic National Wildlife Refuge.

Without environmental labeling standards, consumers could not tell which products and services were truly beneficial. Consumers ended up paying extra for misrepresented products. The media came up with the term "greenwashing" to describe cases where organizations misrepresented themselves as environmentally responsible.

In 1992, the Federal Trade Commission (FTC) stepped in to prevent further deception. The FTC created guidelines for the use of environmental marketing claims such as "recyclable," "biodegradable," "compostable," and the like. The FTC and the U.S. Environmental Protection Agency defined "environmentally preferable products" as products and services that have a lesser or reduced effect on human health and the environment when compared to other products and services that serve the same purpose. The label "environmentally preferable" considers how raw materials are acquired, produced, manufactured, packaged, distributed, reused, operated, maintained, or how the product or service is disposed.

Today, special labels help the public identify legitimate environmentally preferable products and services. Several environmental groups evaluate and certify products and services that meet FTC standards—or their own tougher standards. One popular product that has received certification is shade-grown coffee, an alternative to coffee beans that are grown on deforested land in the tropics.

During the late 1990s, green marketing received a large boost when President Bill Clinton issued executive orders directing federal offices to purchase recycled and environmentally preferable products. Some industries adopted similar policies.

Examples of environmentally-beneficial products and services:

- Paper containing post-consumer wastepaper
- Cereals sold without excess packaging
- Shade-grown coffee beans
- Cleaning supplies that do not harm humans or environment
- Wood harvested from sustainable forests
- Energy-efficient lightbulbs
- Energy-efficient cars
- Energy from renewable sources of energy such as windmills and solar power

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Corliss Karasov

Green Party

The Green Party movement is rooted in sustainable environmental democracy, which derives historically from the early confederacy of five Native-American nations in New York state called the Iroquois Confederacy. The confederacy was matriarchal, cooperative, tribal, and regionally based. As Donella and Dennis Meadows note in their book *Beyond the Limits* (1993), the concepts of **environmental stewardship** and **intergenerational sustainability** originated in the confederacy. American revolutionaries Thomas Paine and Benjamin Franklin incorporated these Iroquoian concepts into their politics. In the last forty years, the democratic model has evolved into the bioregionalist or "green" model of **integrative commons governance**. This political approach is equally based on **electoral consensus**, environmental economics, and public welfare.

environmental stewardship human commitment to care for the environment

intergenerational sustainability ability of a system to remain stable and productive over several generations

integrative commons governance a governing system which recognizes and protects publicly shared resources, usually under local control

electoral consensus the will of the voters

Green Party policy focuses on watershed patterns of resource use and control. Large-scale watersheds, or "bioregions," cross many jurisdictions, for example the Mississippi and Amazon Basins, the Arctic Circle, and war-torn regions. Ultimately, Green Party members, or "Greens," envision an integrated global commons congress, a "United Bioregions of Earth." Greens organize against environmental risks from nuclear power and rainforest destruction to chemical-biological-nuclear warfare, and social risks from military oppression to the enslavement of women and children. Greens organize for human health as well as preservation of **biological capital**.

biological capital oceans, forests, and other ecosystems that provide resources or other values

Primary Green movement source materials are all the nongovernmental organization (NGO) treaties finalized at the 1992 United Nations Conference on Environment and Development (UNCED) Earth Summit in Rio de Janeiro, Brazil. The Green caucus of 30,000 people ratified many comprehensive agreements concerning diverse threats to sustainable society, and developed an entirely new language of public policy discourse. These treaties are of two categories: biological (deforestation, desertification, loss of biological diversity) and social (indigenous rights, militarism, and transnational corporations, or TNCs). The Green Party believes that the TNC global agenda targets all major environmental and community self-determination laws for elimination. These are contested as "nontariff trade barriers" under World Trade Organization (WTO) treaty obligations. Meanwhile, massive, internationally organized street protests against the WTO continued episodically.

Shortly after the 1992 Earth Summit, the number of countries with active Green Parties doubled from thirty-five to approximately seventy. The "European Green Parliament" is well established, and a Green/Social Democrat coalition governs Germany. Green infrastructure in the Americas is strongest in British Columbia. The United States lags far behind Europe: Only parliamentary political systems effectively admit Green proposals.

Operational principles, models, and priorities for the Greens in the United States were developed by Ralph Nader and his associates in the 1970s and 1980s. Nader cowrote the federal Clean Air Act and Clean Water Act, and as the Green candidate in 1996, he opposed WTO supporters President Bill Clinton and Vice President Al Gore in the 2000 presidential elections. Nader's work derives from a 1963 Senate subcommittee testimony given by Rachel Carson, who pointed out that, regarding watershed toxicity, communities had both the "right to know" and the "right to protection" by

government, thus establishing the first conceptual bridge between environmental law and human rights law. SEE ALSO EARTH SUMMIT; LADUKE, WINONA; NADER, RALPH.

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Kender Taylor

Green Revolution

The "green revolution" refers to the widespread introduction of industrial agriculture into developing countries that began in the 1940s. As seen in Norman Borlaug's work on world hunger, its early promoters—led by the Rockefeller Foundation—assumed that increased food production would alleviate hunger in poor countries and thereby help prevent "red" (i.e., communist) revolutions. Although the green revolution has led to impressive increases in agricultural production over the years, critics such as Amartya Sen have argued that poverty and inequality must also be vigorously attacked since the poor typically cannot afford to buy enough food. Others, like Kenneth Dahlberg and Vandana Shiva, have argued that its high social, environmental, and energy costs of the green revolution make it unsustainable.

United States and European seed-breeding technologies devised in the 1930s were used from the 1940s onward to develop *high-yielding varieties* (HYVs) adapted to the climate and soil conditions of different developing countries. Research on maize (corn) begun in Mexico in the 1940s by the Rockefeller Foundation was extended in 1959 to rice in the Philippines in partnership with the Ford Foundation. By the 1960s, fears of famine in Asia caused by rapid population growth led to major aid programs to increase agricultural production though a package of inputs (HYVs, fertilizers, and pesticides) and financial support. Plant breeder Norman Borlaug, who led the Mexican research, was awarded the 1970 Nobel Peace Prize for his contributions to the green revolution. A network of international agricultural research centers managed by the World Bank was also created to further spread the green revolution.

A new phase of the green revolution began in the mid-1980s in response to two emerging global developments. The first was growing international concerns about the increasing gap in wealth between the rich countries of the northern hemisphere and the poor countries of the southern hemisphere, the continuing population explosion, discrimination against women, environmental degradation, the loss of **genetic diversity**, and **global warming**. The international response has been that vigorous pursuit of **sustainable development** is the only answer to these problems. Interest in sustainable agriculture and food systems that are more energy efficient and less socially and environmentally destructive has grown rapidly in all countries. The Rockefeller Foundation, for example, is promoting proposals, made by Conway in his work *The Doubly Green Revolution*, which seeks rural development of the world's poorest regions though sustainable farming systems developed with full farmer participation, including women subsistence farmers.

The second development raising concern is the increasing global power of multinational corporations. Proposed responses have been divided along the same rich-poor lines as with other international problems. In agriculture, new plant genetic engineering techniques, plant and animal patenting, and free-trade agreements have combined to give multinational corporations a significant ability to shape agricultural policies, as well as the structure of food systems world wide. This power raises fundamental questions about the ability of governments to continue to set national food safety and labeling standards. These protect citizens and enable them to choose foods produced in a sustainable manner, which includes providing farm families and farm and food workers reasonable incomes and working conditions. Many farm, environmental, and consumer groups, as well as the poor countries of the world, are seeking ways to protect their food sovereignty and promote more equitable food systems.

Reconciling this increasing corporate power with the need to develop sustainable food and agricultural systems will be a serious source of contention for years to come. SEE ALSO AGRICULTURE; ECONOMICS; ENVIRONMENTAL JUSTICE; SUSTAINABLE DEVELOPMENT.

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Kenneth A. Dahlberg

HIGH YIELDING VARIETIES (HYVS)

These new seed varieties were based on disease-resistant seed varieties found in the developing countries which were crossbred: 1) to make them respond more to fertilizer and irrigation, thus increasing their yield; 2) to make them less sensitive to annual variations in day length so that they can be used in many different latitudes and climatic zones, and 3) with rice, to make them mature faster so that two crops a year can be grown.

genetic diversity the broad pool of genes that insures variety within a species

global warming an increase in the near-surface temperature of the Earth; the term is most often used to refer to the warming believed to be occurring as a result of increased emissions of greenhouse gases

sustainable development economic development that does not rely on degrading the environment

Greenhouse Gases

anthropogenic human-made; related to or produced by the influence of humans on nature

Greenhouse gases are trace gases in the atmosphere that absorb outgoing infrared radiation from Earth and thereby, like a greenhouse, warm the planet. Naturally occurring greenhouse gases (primarily water vapor and carbon dioxide) make the planet habitable for life as we know it. **Anthropogenic** greenhouse gases contribute to further warming, referred to as global warming.

Carbon dioxide (CO_2) is both a natural and anthropogenic greenhouse gas. Anthropogenic inputs of CO_2 mainly from the burning of fossil fuels and deforestation continue to rise, making it the number-one contributor to global warming. Other anthropogenic greenhouse gases include methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), chlorofluorocarbons (CFCs), and hydrofluorocarbons (HFCs). The last three compounds are synthetic greenhouse gases, which did not exist in the atmosphere before the twentieth century. Molecule for molecule, these gases trap more energy than CO_2, but are less abundant in the atmosphere. One molecule of CH_4, for example, traps as much heat as twenty-three molecules of CO_2. SF_6 traps as much heat as 22,200 molecules of CO_2.

In 1997 the Kyoto Protocol proposed legally binding restrictions on greenhouse gas emissions, targeting a 5-percent reduction over 1990 levels by 2012. As of December 2001, 186 countries had ratified the protocol. The United States, however, is not one of them. SEE ALSO Carbon Dioxide; CFCs (Chlorofluorocarbons); Global Warming; Methane; Montréal Protocol; NO_x; Treaties and Conferences.

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Marin Sands Robinson

Greenpeace

biodiversity refers to the variety and variability among living organisms and the ecological complexes in which they occur; for biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity; thus, the term encompasses different ecosystems, species, and genes

Greenpeace is the largest environmental organization in the world with 2.8 million supporters worldwide and national as well as regional offices in forty-one countries across Europe, the Americas, Asia, and the Pacific. It is a nonprofit organization founded in 1971 and based in Amsterdam, the Netherlands. Greenpeace is one of the nongovernmental organizations that have consultative status to the United Nations, and is an active participant in international conferences on the environment such as the 1992 Rio Earth Summit and the 2002 Johannesburg Earth Summit and their treaty processes. As a global organization, Greenpeace focuses on what it feels are the most crucial worldwide threats to the planet's **biodiversity** and environment. Using nonviolent means, it campaigns to stop climate change, protect the oceans, stop whaling, stop genetic engineering, stop nuclear threats, eliminate toxic chemicals, and encourage sustainable development. Greenpeace does not

accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace was founded by a small group of activists in an old fishing boat, the *Phyllis Cormack.* They wanted to stop and "bear witness" to U.S. underground nuclear testing at Amchitka, a tiny island off the west coast of Alaska. Although their boat was intercepted and the bomb was detonated, nuclear testing there ended a year later. Greenpeace's creative communication and media-savvy tactics of bringing vivid images to the public, of individuals confronting huge corporations and governments, and of using specific cases to highlight broader issues sparked worldwide interest and changed the way advocacy groups conduct campaigns. In one of its best-known campaigns, activists placed small inflatable boats called zodiacs between whaling ships and the whales to protest the hunting practice and highlight toxic threats facing oceans. In 1987, Greenpeace's flagship the *Rainbow Warrior* was preparing to lead a peace flotilla of ships from New Zealand to the island of Moruroa to peacefully protest against French nuclear testing. Three days after arrival in Auckland, French agents bombed and sank the *Rainbow Warrior* in the harbor, killing Greenpeace photographer Fernando Pereira. After two years of international arbitration, a panel of three arbitrators awarded a U.S. $8.159 million damage claim settlement in favor of Greenpeace. The money, paid by the French government, was used in part by Greenpeace to support a worldwide fleet of ships and its campaigns for a nuclear- and pollution-free Pacific. SEE ALSO Activism; Antinuclear Movement; Arbitration; Earth Summit; Environmental Movement; Ethics; Global Warming; Hazardous Waste; Mass Media; Nongovernmental Organizations (NGOs); Ocean Dumping; Persistent Organic Pollutants (POPs); Petroleum; Public Participation; Technology, Pollution Prevention; Treaties and Conferences; War; Water Pollution: Marine.

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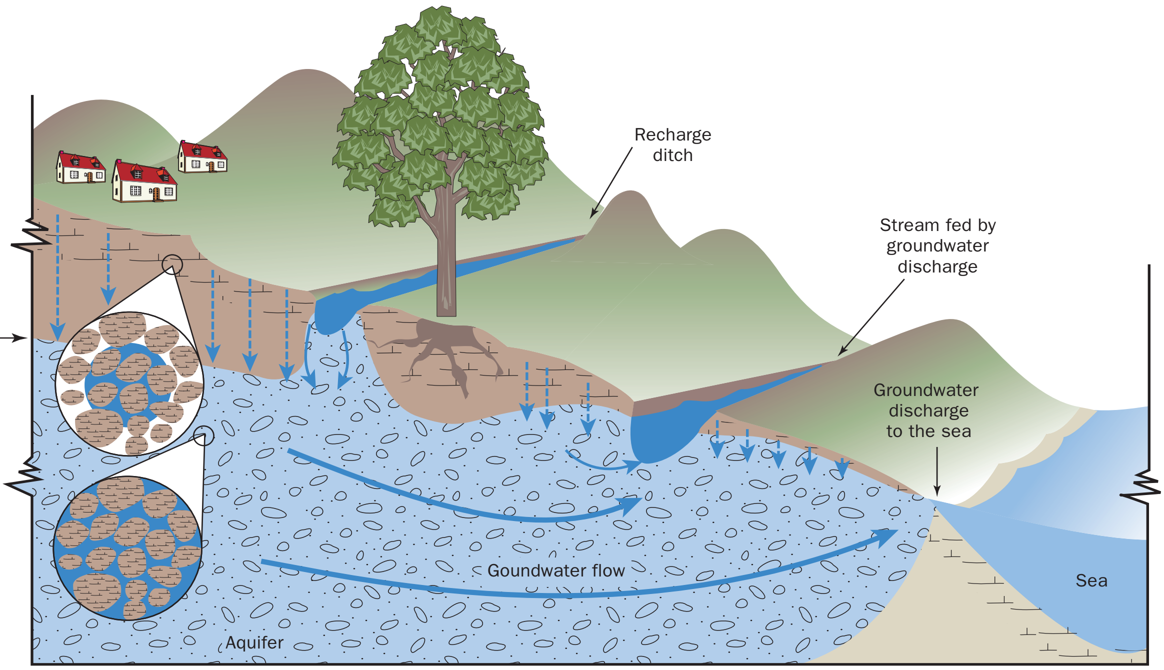
Susan L. Senecah

Groundwater

Groundwater is the water that exists below the land surface and fills the spaces between sediment grains and fractures in rocks. A geologic formation saturated with groundwater is considered to be an aquifer if it is sufficiently permeable as to allow the groundwater to be economically extracted. It is replenished naturally through the infiltration of rainfall and artificially through the irrigation of crops. Soluble chemicals in rainwater (like NO_x in acid rain) or at the land surface (like pesticides) can be transported downward with **percolating** water to reach groundwater. Underground petroleum storage tanks (USTs) or buried pipelines also pose threats if they should leak. Over 400,000 leaking USTs have been identified in the United States as of 2001. Dissolved chemicals are transported with the flowing groundwater. Once groundwater is contaminated, remediation can be expensive and time-consuming; billions of dollars are spent annually in the United States on the remediation of contaminated sites and

percolating moving of water downward and radially through subsurface soil layers, usually continuing downward to groundwater; can also involve upward movement of water

FLOW OF GROUNDWATER



SOURCE: Adapted from Montana State University.

some of the groundwater contamination cannot be reversed. Groundwater discharges naturally into lakes, rivers, oceans, and springs. It is also extracted via pumping wells.

Approximately 80 percent of municipal water systems and close to 99 percent of rural residents in the United States rely on groundwater. In total, approximately 51 percent of the U.S. population depends on it for their water supply. The 1986 amendments to the Safe Drinking Water Act requires that well head protection plans be developed by each state to protect the land around municipal water supply wells from contamination. Individuals can help protect groundwater by disposing of household chemicals properly and fertilizing plants in limited quantities and can help conserve groundwater by limiting water use at home by taking shorter showers, not running water while brushing teeth, running dish and clothes washers with full loads, fixing leaky faucets and pipes, and limiting plant watering in the garden.

recharge the process by which water is added to a zone of saturation, usually by percolation from the soil surface (e.g., the recharge of an aquifer)

land subsidence sinking or settling of land

If withdrawals exceed **recharge** over a long period, groundwater levels fall and aquifers can become depleted. This results in decreased groundwater discharge and may adversely impact on ecosystems dependent on an aquatic habitat. Excess lowering of groundwater levels may result in **land subsidence**. In central California, for instance, groundwater withdrawals from 1930 to 1955 for crop irrigation caused approximately three meters of subsidence. In some arid regions (like the Middle East), little groundwater recharge occurs because of low amounts of rainfall and high amounts of evaporation. Ancient groundwater that infiltrated thousands of years ago during climates wetter than those of the present is being extracted via pumping. This practice is termed *groundwater mining* because groundwater at this location is

a nonrenewable resource that is being depleted. SEE ALSO DRINKING WATER; PESTICIDES; SUPERFUND; UNDERGROUND STORAGE TANKS; WATER POLLUTION.

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Karen M. Salvage

Halon

Halons and other halocarbons (carbon- and halogen-containing compounds), such as chlorofluorocarbons (CFCs), are responsible for the breakdown of stratospheric ozone and the creation of the Antarctic ozone hole. Halons are a **subset** of a more general class of compounds known as halocarbons. Halons contain carbon, bromine, fluorine, and, in some cases, chlorine. Halons are entirely human-made and are used primarily in fire extinguishers.

subset a smaller group within a larger one

One of the most common halons has the chemical formula $CBrClF_2$, denoted as H-1211 in an industry-devised shorthand. The compounds live long enough in the atmosphere (eleven years in the case of H-1211) to reach the stratosphere, an upper region of the atmosphere located between fifteen and fifty kilometers above the earth's surface, where the sun's more intense ultraviolet (UV) radiation breaks down the molecule and releases **chemically active** bromine and chlorine atoms. These free atoms enter into cycles of chemical reactions that destroy ozone.

chemically active able to react with other chemicals

An international agreement known as the Montréal Protocol was forged in 1987 and subsequently amended to phase out and eventually end the use of ozone-depleting chemicals. Under the terms of the agreement, developed countries must first phase out the use of halons and other halocarbons. Developing countries are given additional time to acquire the new technologies needed to meet the requirements. SEE ALSO CFCS (CHLOROFLUOROCARBONS); MONTRÉAL PROTOCOL; OZONE.

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Christine A. Ennis

Hamilton, Alice

WORKERS' ADVOCATE
(1869–1970)

During the Progressive Era, Alice Hamilton became part of the revolution of thought about the causative factors of disease, explicitly linking environmental

From left to right: Mrs. F. Louis Slade, Marion Edward Park, and Alice Hamilton. (©Bettmann/Corbis. Reproduced by permission.)

factors to serious illnesses or epidemics. To satisfy her passion for social activism, Hamilton joined Jane Addams in Chicago at Hull House, the first of many settlement houses in America.

Hamilton focused her activities on worker health, an issue neither employers nor the federal government expressed much concern about at the time. One of Hamilton's main contributions to eliminating worker hazards was a study of the health effects of lead. Through an exhaustive investigation, Hamilton demonstrated the harmful effects of the toxin on humans. She also conducted research connecting typhoid to flies and improper sewage disposal, and linked the use of white phosphorous to the disease "phossy jaw."

In 1925, while serving as the first female staff member at Harvard University, Hamilton published her classic *Industrial Poisons in the United States*. Her work continued to emphasize several themes over the course of her life, including the effects of many toxic substances, the improvement of safety standards for workers, and the future effects of toxins on human health. Many regarded Hamilton as one of America's best-known experts on occupational hazards. SEE ALSO ACTIVISM; ADDAMS, JANE; ENVIRONMENTAL MOVEMENT; INDUSTRY; OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA); POLITICS; PROGRESSIVE MOVEMENT; PUBLIC POLICY DECISION MAKING; SETTLEMENT HOUSE MOVEMENT; WORKERS HEALTH BUREAU.

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Elizabeth D. Blum

Hayes, Denis

AMERICAN ENVIRONMENTALIST; ORGANIZER OF FIRST EARTH DAY (1944–)

grassroots individual people and small groups, in contrast to government

Denis Hayes, at the time a twenty-five-year-old Harvard law student, organized the first Earth Day celebration on April 22, 1970. Earth Day inspired the **grassroots** participation of twenty million people in the United States and marked the coming-of-age of the environmental movement. It brought concerns about pollution and the environment into the awareness of the American public, and Congress responded by passing a series of environmental acts during the following years.

teach-in educational forum springing from a protest movement (derived from sit-in protests)

As an intern for Wisconsin's Democratic senator and environmentalist Gaylord Nelson, Hayes was selected to organize and coordinate **teach-ins**, addressing topics such as pollution and environmental degradation, on college campuses across the United States. Students inspired by the teach-ins and the ensuing publicity that Hayes orchestrated went on to organize thousands of cleanup activities and protest actions to mark the first Earth Day in 1970.

Following the first, overwhelmingly successful, Earth Day, Hayes became an alternative energy expert: He worked for Worldwatch Institute, wrote *Rays of Hope* (1977) about solar energy, and directed the government's

Solar Energy Research Institute. He organized a twentieth-anniversary Earth Day celebration in 1990, in which 200 million people from 141 countries worldwide participated.

In 1978, Hayes was awarded the American Institute for Public Service's Jefferson Medal for Greatest Public Service by an United States citizen under thirty-five years of age. He was also recognized by the Audubon Society in 1998 as one of the twentieth century's one hundred "Champions of Conservation."

Since 1993, Hayes has directed the Bullitt Foundation of Seattle, which funds environmental protection and restoration projects in the Northwestern United States. SEE ALSO ACTIVISM; EARTH DAY; LAWS AND REGULATIONS, UNITED STATES; NELSON, GAYLORD; POLITICS.

Denis Hayes. (©Dan Lamont/Corbis. Reproduced by permission.)

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Anne Becher and Joseph Richey

Hazardous Waste

The Resource Conservation and Recovery Act (RCRA), enacted in 1976, defines hazardous waste as a liquid, solid, sludge, or containerized gas waste substance that due to its quantity, concentration, or chemical properties may cause significant threats to human health or the environment if managed improperly. U.S. legislation considers a waste hazardous if it is corrosive, flammable, unstable, or toxic. Sources of hazardous waste may include industry, research, medical, household, chemical producers, agriculture, and mining, as well as many others.

Most hazardous waste comes from industrial sources. The EPA specifies four different categories of hazardous waste that are subject to regulation: hazardous wastes from nonspecific sources involved in industrial processes such as spent halogenated solvents; hazardous wastes from specific industrial sources, such as untreated wastewater from the production of the herbicide 2,4-dichlorophenoxyacetic acid (2,4,-d); commercial chemical products that may be discarded (such as benzene) used in the manufacture of drugs, detergents, lubricants, dyes and pesticides; and wastes that are classified as toxic, such as vinyl chloride. Hazardous waste from many industrial processes include solvents such as methylene chloride, a probable carcinogen that is commonly used in paint removers. Trichloroethylene, a solvent that has been found in groundwater is monitored and regulated in drinking water in the United States. Drinking or breathing high levels of trichloroethylene can lead to damage of the liver, lung, and nervous system. In many industries the sludge remaining after treatment of wastewater accounts for much of the generated hazardous waste. Sludges and wastewater from electroplating operations commonly contain cadmium, copper, lead, and nickel. These heavy metals are found in the sediment of Lake Huron and have been associated with degradation of benthos and planktonic communities. Heavy metals can impact the health of humans and wildlife in a variety of ways: lead interferes with the

nervous system and can lead to learning disabilities in children and cadmium accumulates in humans and animals and can lead to kidney disfunction. Household products that contain hazardous ingredients are not regulated under RCRA but should be disposed of separately from municipal garbage following label instructions. Household hazardous waste (HHW) can include used motor oil, paint thinners and removers, wood preservers, batteries, fluorescent lights that contain mercury, and unused pesticides.

The U.S. Environmental Protection Agency (EPA) and state regulatory agencies collect information about the generation, management, and final disposal of hazardous wastes regulated under RCRA. This report gives detailed data on hazardous waste generation and waste management practices for treatment, storage, and disposal facilities.

Waste Minimization and Recycling

Recycling and waste minimization may be the best ways to deal with hazardous waste. Waste minimization reduces the volume of waste generated, whereas recycling means that less hazardous waste requires disposal. Techniques for waste minimization may include audits, better inventory management, production process/equipment modifications, and operational/maintenance procedures. Raw material changes, volume reductions, nonhazardous material substitutions, reuse, or recovery also reduce hazardous waste production. For example biodegradable, nontoxic lactate esters are solvents manufactured from renewable carbohydrate sources that can be substituted for toxic halogenated solvents.

The EPA's Industrial Toxics Project is a nonregulatory program initiated in 1990 to achieve, voluntarily, overall reductions for seventeen toxic chemicals reported in the government's Toxics Release Inventory (TRI), including cadmium, lead, mercury, trichloroethylene, and toluene. The recycling of waste through waste exchanges is one aspect of industrial ecology and another way to address the issue of hazardous waste disposal. For example the sludge that accumulates in scrubbers removing sulfur dioxide from power plant smokestacks contains calcium sulfate, which can be recycled in wallboard. Waste exchange also promotes the use of one company's waste as another company's raw material. Waste exchanges typically list both available and desired materials. Several regional waste exchanges exist, as well as exchanges within small geographic regions. Some exchanges charge for their services, whereas others are supported by grants.

Disposal Options and Problems

Disposal options for hazardous waste include landfills, **injection wells**, incineration, and **bioremediation**, as well as several others. The greatest concern with the disposal of hazardous waste in landfills or injection wells is that toxic substances will leak into surrounding groundwater. Groundwater is a major source of drinking water worldwide and once it is contaminated, pollutants are extremely difficult and costly to remove. In some instances, it is impossible to remove groundwater contamination. The ideal disposal method is the destruction and conversion of hazardous waste to a nonhazardous form. New technology for hazardous and mixed low-level radioactive waste conversion includes a high-temperature plasma torch that converts low-level radioactive wastes to environmentally safe glass. Conversion to

injection well a well into which fluids are pumped for purposes such as underground waste disposal, improving the recovery of crude oil, or solution mining

bioremediation use of living organisms to clean up oil spills or remove other pollutants from soil, water, or wastewater; use of organisms such as non-harmful insects to remove agricultural pests or counteract diseases of trees, plants, and garden soil

Workers wearing hazardous materials suits, neutralizing hazardous materials. (©Pete Saloutos/Corbis. Reproduced by permission.)

environmentally safe substances can be very expensive for some types of hazardous wastes and technically impossible for others, creating the need for alternative disposal methods.

The most common form of hazardous waste disposal in the United States is landfilling. Hazardous waste landfills are highly regulated and are required to include clay liners, monitoring wells, and groundwater barriers. The 1984 Hazardous Solid Waste Amendments require the monitoring of groundwater near landfills for thirty years. Injection wells may be used to inject hazardous waste deep into the earth, but problems result with aquifer contamination and the ultimate fate of the hazardous waste after injection is unknown.

Incineration may be an effective way to convert hazardous waste into a nonhazardous form while greatly decreasing its volume. The waste is burned and converted into carbon dioxide, water, and inorganic by-products. The problems associated with incineration are high capital and operating costs, and the disposal of ash, which may contain hazardous substances. In addition, incinerating wastes can cause mercury and dioxin air pollution. Bioremediation may also be used *in situ* or *ex situ* to convert hazardous wastes to nontoxic by-products using microorganisms and natural degradation processes. Biodegradation requires very long treatment times and it may be difficult to control or enhance natural degradation processes. Phytoremediation, the process by which plants absorb and in some cases degrade hazardous

substances in the environment, is being investigated as an emerging cleanup technology. For example poplar trees have been shown to break down the herbicide atrazine, mustard plants will remove lead from soil, and the alpine pennycress plant will take large amounts of heavy metals and also uranium from soil.

When hazardous waste is to be transported off-site for disposal, the waste generator prepares a shipping document called a manifest. This form must accompany the waste to its final destination and is used to track the waste's movements from "cradle to grave."

Hazardous Waste Production in the United States

Facilities that produce hazardous waste, usually as a result of an industrial process, are considered large-quantity generators (LQG) or small-quantity generators (SQG) depending on the quantities produced. Hazardous waste may be transported to alternate locations to be treated, stored, or disposed of, or may be managed at the place of generation.

In 1995, 20,873 LQGs produced 214 million tons of hazardous waste regulated by RCRA. There were 3,489 fewer LQGs and a reduction of 44 million tons of waste by 1995 compared to 1993. The five states generating the largest amount of hazardous waste were Texas (69 million tons), Tennessee (39 million tons), Louisiana (17 million tons), Michigan (13 million tons), and Illinois (13 million tons), accounting for 70 percent of the national totals.

The industrial trade of hazardous waste has become an extensive problem. Many third world countries accept large volumes of hazardous waste for disposal in return for sizable financial compensation. Unfortunately, the large profits reaped by such poor countries do not compensate for the long-term environmental impacts from improperly managed hazardous waste. Many wastes have also been dumped illegally on international shores where environmental regulation and controls are often lacking. SEE ALSO ABATEMENT; BROWNFIELD; CLEANUP; GREEN CHEMISTRY; INCINERATION; INDUSTRIAL ECOLOGY; INJECTION WELL; LANDFILL; MEDICAL WASTE; RADIOACTIVE WASTE; RESOURCE CONSERVATION AND RECOVERY ACT; WASTE, TRANSPORTATION OF.

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Margrit von Braun and Deena Lilya

Health Effects

See Health, Environmental; Health, Human

Health, Human

Environmental Health in the Preindustrial World

Human health—and human disease—have always been intimately connected to the environment. The environment contains the positive, in the form of air, water, and nutrients, and the negative, in the form of bacteria, viruses, and toxins. Humans have developed elaborate defense systems to protect against adverse environmental effects. These include immune systems that attack bacteria and other foreign bodies, DNA repair enzymes that defend the integrity of genetic structure, and metabolizing enzymes that degrade ingested compounds and prepare them for excretion. When these systems become overwhelmed or operate inefficiently, disease and death can occur.

The awareness that the environment influences disease dates back at least to the time of Hippocrates. The first *proven* case of an illness linked to an environmental cause did not occur, however, until 1854 in London when physician John Snow showed that water pollution was responsible for a local outbreak of cholera. His proof was simple: after disabling the use of a contaminated well by removing its pump handle, a subsequent reduction in new cholera cases was noted.

The bacterial contamination of water polluted by human or animal wastes was probably the most common environmental problem of the preindustrial world. Its control in the twentieth century represents one of the greatest triumphs of public health. The chlorination of public drinking water to prevent waterborne diseases began in the early 1900s in the United States and is responsible for the virtual elimination of cholera, typhoid, dysentery, and hepatitis A in this country.

Environmental Health in the Postindustrial World

Pollution itself, particularly from human activities, is not a modern phenomenon. The preindustrialized world certainly offered many opportunities for a polluted existence. Wood fires, the close proximity of livestock, and mining and smelting operations all would have presented conditions for polluting either the air or water, or both. Following the Industrial Revolution, however, the combined concentrations of people and industrialized processes conspired to create pockets of intensely polluted environments. For instance, the air surrounding Pittsburgh, Pennsylvania, and other steel mill towns was laden with particulates, and pulp and paper mills would release the stench of sulphurous gases into the air and discharge dioxin-contaminated effluents into the water. Such activities, though, brought with them jobs and the financial incentive for communities to ignore the noxious conditions under which some were forced to live. This level of tolerance did not last, however. In the post-World War II world, several incidents around the world began to focus attention on the consequences of polluting the natural environment.

One of these incidents occurred in 1948 in the steel mill town of Donora, Pennsylvania. A pollutant-induced smog was found to be responsible for twenty-one deaths, providing clear proof that the effects of air pollution were not limited to aesthetics. Later, in 1952, London, England, also experienced a “killer smog” blamed for the deaths of 4,000 people. Governments began to act to protect the air from industrial and automobile pollution.

Diarrheal diseases (caused by unsafe water, inadequate sanitation, and poor hygiene) and acute respiratory infections associated with indoor air pollution caused by burning wood, peat and other biomass fuels killed at least three million children under age five in the year 2000. The World Health Organization says that 40 percent of global disease caused by environmental factors falls on children.

What these examples had in common was that the connection between a pollutant and a health outcome was fairly unambiguous. Severe illness and death were the end points examined and both would occur fairly soon after exposure to a highly polluted situation. This lack of ambiguity was vital in fueling the determination to reduce pollutant levels, regardless of the economic costs to some industries. The pollution control measures enacted led to improvements in environmental quality. But were they enough?

In 1962 Rachel Carson published *Silent Spring*, alerting the world to the unintended consequences of chemical pesticide use. Her concern was the rampant use, and often overuse, of insecticides, fungicides, and herbicides in the post-World War II world. Not confined to agricultural fields, these products leached into ground water, rivers, lakes, and the food supply. Her book brought to the political arena the concept that synthetic chemicals could be responsible for cancer and other diseases. Her warnings proved prescient. The chlorinated hydrocarbons, such as the insecticide DDT (dichlorodiphenyltrichloroethane) [1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane] and its metabolite DDE (dichlorodiphenyl dichloroethylene) [1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene], were discovered to not only persist in the environment but to concentrate at greater than ambient levels as they moved up the food chain. Many of these compounds, DDT and DDE included, have the ability to interfere with normal hormone levels in the body, leading to the disruption of endocrine systems. DDT was found to cause thinning of eggshells and a subsequent drop in the population of large birds of prey such as the eagle. This information led to the banning of DDT in the United States in the 1970s. Although DDT was outlawed based on evidence that it was a reproductive toxin in some wildlife species, evidence now exists that it is also a human reproductive toxin. Recent analysis of serum taken from pregnant mothers enrolled in the U.S. Collaborative Perinatal Project during the 1960s revealed that women exposed to DDE were more likely to give birth prematurely, and to babies who were unusually small. Both of these events can adversely affect the infant's long-term health.

Difficulties in Determining Environmental Health Effects at Low Exposure Levels

Pollution levels in most of the industrialized world are now relatively low. Lowering these levels further will be more expensive and, in the absence of convincing public health need, it will be more difficult to create the public will for additional reductions. At the same time, the health consequences of low levels of pollutants are undeniably more difficult to determine. This difficulty arises from two facts. The first is that people differ, often significantly, in their response to environmental toxicants. As mentioned earlier, organisms have evolved a complex environmental response machinery to protect against foreign compounds or xenobiotics. Such machinery includes DNA repair enzymes and metabolizing enzymes in the liver and other organs. Except in a few rare cases, everyone has the genes coding for these enzymes. But there is tremendous variability in these genes and some variants are more effective than others. Thus, some people are more sensitive to specific environmental toxicants and some people less so. Even under the same exposure conditions, there can be wide variation in how people's bodies react to environmental agents. This variability in the general population

Protestors outside the Cleveland, Ohio, city hall on January 20, 1970, protesting the city's air pollution. (©Bettmann/Corbis. Reproduced by permission.)

can often mask very real effects that occur in a sensitive segment of the population.

The second difficulty is that age and the timing of exposures can greatly influence both sensitivity to an environmental agent and the type of health effect it will cause. Infants and children can be particularly vulnerable and can sustain lifelong damage at exposures that have no impact in adults. As an example, the metal lead is a known **neurotoxicant**. At high exposures of lead (80 µg/dL or higher in the bloodstream), encephalopathy, epilepsy, mental retardation, and blindness are the probable outcomes. Thus fifty years ago a level of 60 µg/dL of lead would be acceptable because immediate neurological symptoms did not occur in adults at these levels.

neurotoxicant chemical that is toxic to neurons, or brain cells

The "concern" threshold has been steadily dropping, however, because of new information about subtle health effects of lead, as well as the greater vulnerability of children to lead exposures. Now banned from use in products such as household paint and automotive gasoline, the "concern" threshold for lead is currently 10 µg/dL of lead in the bloodstream of children. This level was determined based on research findings that even low lead exposures can cause unexpected problems for children. There is now evidence that every 10 µg/dL of lead in the bloodstream of children is associated with a two- to three-point IQ deficit. Although these decrements are low, they translate into later problems in school, particularly decreased attention spans, increased aggression as juveniles, and failure to graduate from high school. Thus,

A female student uses an inhaler for her asthma. (© Angela Hampton; Ecoscene/ Corbis. Reproduced by permission.)

regulatory standards based on studies in adults can potentially fail to protect children and other sensitive groups.

Childhood is not the only vulnerable life stage. Puberty could represent another sensitive time point. Exposure to hormonally active agents (HAA) such as DDT, polycholorinated biphenyls (PCBs), dioxins, and certain classes of plasticizers, could adversely affect hormonally sensitive tissue, such as breast tissue. For example, women exposed to these compounds might be at greater risk of breast cancer, particularly if their exposures occur around puberty. The critical exposures could occur much earlier than clinical

manifestations of disease, though, making it difficult to establish an association between the exposure and breast cancer. Additionally, the aging body might be less able to hold up against a lifetime of low-level, but persistent, environmental assaults and could begin to experience **neurodegeneration**, cancers, or heart disease as a consequence.

neurodegeneration loss of function and death of brain cells

Environmental Health in the Twenty-first Century

Most diseases arise from the interaction of several events: an individual's inherited genetic susceptibility, his or her subsequent environmental exposures, and modifying factors such as behavior, age, and the time of exposure. The health consequences of low-level environmental exposures are more likely to be discovered when studies are designed to accommodate this greater complexity of knowledge. The payoff of such knowledge is potentially tremendous because the environment has been shown to play a role in so many chronic diseases. Recent twin studies in Scandinavia show that non-genetic influences, presumably environmental, account for more than 50 percent of cancer risk. For Parkinson's disease, environmental triggers might account for the greater number of **late-onset** diagnoses. And for **autoimmune** diseases, the **concordance** among identical twins usually falls in the 25- to 40-percent range, suggesting that environmental influences have a major impact on either the initiation or progression of these diseases. Thus, accurate and realistic assessments of environmental contributions to diseases are critical.

late-onset occurring in adulthood or old age

autoimmune reaction of the body's immune system to the body's own tissues

concordance state of agreement

Fortunately, the United States Department of Health and Human Services (DHHS), through its Human Genome Project [see sidebar], is providing the tools necessary for a more thorough investigation of gene-environment interactions in disease development. This project has identified the **nucleotide** sequences of human genes, including environmental response genes. Additionally, it has led to the development of new assaying techniques that can assess the activity (or expression) of hundreds of genes simultaneously. These events create the opportunity to systematically catalogue the genetic variation of environmental response genes and to determine the biological consequence of these variations. This information, generated by the United States Environmental Genome Project (funded by the National Institute of Environmental Health Sciences and found on their web site http://niehs.nih.gov), can subsequently be used in population studies to determine the health effects of environmental pollutants at relatively low exposure levels.

nucleotide building block of DNA and RNA in a cell

Human understanding of environmental disease risks is constantly evolving. New understanding, particularly of how individuals differ in response to environmental agents, will reveal new public health strategies. Even current successes, such as the chlorination of water supplies mentioned earlier, are being reassessed. It is now known that organic compounds in water can react with chlorination to produce **halogenated organic compounds** that are suspected bladder carcinogens. Though the cancers potentially caused by these disinfection by-products are much less frequent than the deaths that would occur without disinfection, they are nonetheless troubling. New technologies such as **chloramination** and **ozonation** are increasingly being substituted for chlorination and may lead to even better public benefit from water disinfection.

halogenated organic compounds organic (carbon-containing) compounds containing fluorine, chlorine, bromine, iodine, or astatine

chloramination use of chlorine and ammonia to disinfect water

ozonation application of ozone to water for disinfection or for taste and odor control

HUMAN GENOME PROJECT

The Human Genome Project (HGP) is an international research effort to sequence and map all of the genes—together known as the genome—of humans. Many of these genes are environmental response genes and are being further investigated under the Environmental Genome Project for their role in environmentally associated diseases. Contributors to the HGP include the National Institutes of Health (NIH), the U.S. Department of Energy (DOE), numerous universities throughout the United States, and international partners in the United Kingdom, France, Germany, Japan, and China.

The HGP also includes efforts to characterize and sequence the entire genomes of several other organisms, many of which are used extensively in biological research. These organisms include mice, fruit flies, and roundworms. Identification of the sequence or function of genes in model organisms is an important approach to finding and understanding the function of human genes.

Information on the HGP can be found on the website of the National Human Genome Research Institute (NHGRI) at http://www.nhgri.nih.gov.

Environmental regulation and pollution control will remain an important cornerstone of public health policy in the twenty-first century. Because the focus is on prevention, rather than disease treatment, pollution control is a highly cost-effective means of ensuring public health. The cost-effectiveness can only be realized, however, when it is based on an accurate determination of the real human health consequences of environmental exposures. This information is well worth generating, given the broad array of environmentally associated diseases. These include cancer, infertility, autoimmune diseases, birth defects, heart disease, and neurodegeneration. In addition to regulatory policy, pollution control can also affect social policy. In the United States there is a measurable disparity in the health status of poor populations compared to their affluent counterparts. Given that the poor more often live in contaminated environments and work in hazardous occupations, improved pollution control might well lead to a reduction in such current health disparities. It is only when the health of all citizens is protected that a nation can realize its full potential. SEE ALSO ASBESTOS; ASTHMA; CANCER; CRYPTOSPORIDIOSIS; DDT (DICHLORODIPHENYL TRICHLOROETHANE); DONORA, PENNSYLVANIA; ENDOCRINE DISRUPTION; INDOOR AIR POLLUTION; LEAD; MERCURY; RISK; SNOW, JOHN; WATER TREATMENT.

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Kenneth Olden and Janet Guthrie

Healthcare Waste *See Medical Waste*

Heavy Metals

The heavy metals, which include copper (Cu), zinc (Zn), lead (Pb), mercury (Hg), nickel (Ni), cobalt (Co), and chromium (Cr), are common trace constituents in the earth crust. Their concentrations in the ambient environment have increased dramatically since the Industrial Revolution, as have lead and copper since Roman times. Many of these metals play an essential role in human physiology. For example, the enzymes that synthesize DNA and RNA contain zinc ions, and cobalt is an integral part of coenzyme B_{12} and

LIST OF DRINKING WATER CONTAMINANTS AND MCLs

Contaminant	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	TT[3]; Action level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Lead	TT[3]; Action level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands

Notes
[1]Definitions:
Maximum Contaminant Level (MCL)–The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
Treatment Technique–A required process intended to reduce the level of a contaminant in drinking water.
[2]Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.
[3]Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

SOURCE: U.S. Envionmental Protection Agency. Ground Water and Drinking Water. Available from http://www.epa.gov/safewater/mcl.html#/mcls

vitamin B_{12}. It is possible to be deficient in these metals, or to have an optimal or a damaging or lethal intake. However, nonessential elements such as chromium, lead, and mercury have little or no beneficial role in the human body, and the daily intake of these metals is often toxic or lethal. Many heavy metals cause nervous-system damage, with resulting learning disorders in children. Ingestion of mercury can cause the severe breakdown of the nervous system, and metals such as lead and nickel can cause autoimmune reactions. Chromium occurs in a relatively harmless form and a much more dangerous, oxidized **hexavalent** form. Several studies have shown that chromium (VI) compounds can increase the risk of lung cancer and that ingesting large amounts of chromium (VI) can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death, according to the Agency for Toxic Substances and Disease Registry. The dangers of hexavalent chromium in drinking water were popularized in the movie *Erin Brockovich*. Many fish are very sensitive to heavy-metal pollution. For example, trout cannot live in waters that contain more than about five parts per

hexavalent an oxidation state characterized by the ability to make six bonds; symbolized by (VI)

billion of copper. Heavy-metal contamination is very widespread, especially lead and mercury.

Most heavy-metal contamination stems from high-temperature combustion sources, such as coal-fired power plants and solid-waste incinerators. Local metal sources may include metal-plating industries and other metal industries. The use of leaded gasoline has led to global lead pollution even in the most pristine environments, from arctic ice fields to alpine glaciers. The metal **fluxes** from point sources have been strictly regulated, and the introduction of unleaded gasoline has taken a major lead source away. Several sites with severe heavy-metal pollution have become Superfund sites, most of them still under study for decontamination. Site decontamination can be done with large-scale soil removal and metal stripping, or through more gradual methods, like phytoremediation. Nonetheless, even today metals are delivered from the atmosphere to the landscape. In the United States, drinking water is monitored for heavy metals to ensure that their concentration falls below the safe limit or maximum contaminant level (MCL) set by the Environmental Protection Agency. Many urban estuaries like Boston Harbor, San Francisco Bay, and Long Island Sound are severely contaminated with heavy metals. These sedimentary basins will remain polluted for decades, and a small percentage of the sediment-bound metals is released back into the water and occasionally transformed into more dangerous forms. SEE ALSO ARSENIC; HEALTH, HUMAN; LEAD; MERCURY; RISK; SUPERFUND.

flux 1. a flowing or flow; 2. a substance used to help metals fuse together

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Johan C. Varekamp

History

Pollution is not a new phenomenon. In fact, it is older than most people realize. Archeologists digging through sites of Upper Paleolithic settlements (settlements of the first modern humans, between forty thousand and ten thousand years ago) routinely find piles of discarded stone tools, and the litter from the making of these tools. One could even argue that the first use of wood-burning fire ushered in the era of air pollution. Lead pollution from Roman smelters can be traced all across Europe. Yet all this early pollution was limited in its effects on the environment. As humans moved from nomadic to settled societies, however, pollution increased in magnitude, becoming a real problem for the environment and its human and nonhuman inhabitants.

Although pollution of major proportions has been a problem since the centuries preceding the Middle Ages, it is worth noting that after World War II, the type of pollution involved changed significantly. Industries began manufacturing and using synthetic materials such as plastics, polychlorinated biphenyls (PCBs), and inorganic pesticides like dichlorodiphenyl trichloroethane (DDT). These materials are not only toxic, they also accumulate in the environment—they are not biodegradable. Thus, increased rates of cancers, physical birth defects, and mental retardation, among other health problems, are now being observed. A worrisome loss of biodiversity

The *Exxon Valdez* leaking oil; the slick is visible along side of ship. (Courtesy of Richard Stapleton. Reproduced by permission.)

exists in the environment—animal and plant species become extinct at an alarming rate. There is an increased risk of catastrophic industrial accidents, such as the one that occurred in Bhopal, India. The tremendous cleanup costs of hazardous waste dumps, and the difficulty in disposing of these chemicals safely, assure that water, land, and air pollution will continue to be a problem for generations to come. Throughout history and to this day, pollution touches all parts of the environment—the water, the air, and the land.

Water Pollution

Water is essential to life. That is why most human settlements always began near a water source. Conflicts over control of such sources started in ancient times and continue today, as evident in the Middle East, for example. Israel's National Water Carrier project was the target of attacks by neighboring Arab countries and an escalating factor in the tensions that led to the 1967 Six-Day War.

Unfortunately, the importance of *clean* water was not understood until the second half of the nineteenth century, a relatively recent development. In ancient Rome, sewers carried human waste into the Tiber River. By 312 B.C.E. the river was so polluted the Romans had to construct aqueducts to obtain clean drinking water. The pollution of water with raw sewage was the catalyst for many typhoid and cholera outbreaks throughout the centuries, in many parts of the world. Even today, in numerous developing nations,

cholera still kills tens of thousands each year because clean drinking water is not available, or accessible, to everyone.

The connection between water pollution with human waste and the outbreaks of diseases such as cholera was not understood until the 1850s. In 1854, a devastating cholera outbreak gripped the Soho part of London, centering around the Broad Street well. A physician named John Snow, in what has become one of medicine's most celebrated sleuthing cases, deduced that the cause of the outbreak was contamination of the Broad Street well. Since no one believed him, Snow suggested taking off the well pump's handle. Once the well was not in use, the epidemic ended. The cause was later traced to washing a sick baby's dirty diapers in a cesspool that seeped into the well. Unfortunately for Soho, calls for eliminating cesspools from the vicinity of wells in that area went unheeded for quite some time.

In the United States, human waste was carried in American rivers for centuries. Not only were freshwater sources used as sewage dumps in most of the Western world (certain Asian countries used human waste as fertilizer, instead), but industrial waste was also discarded in rivers and streams. Leather tanning waste and butchering waste were frequent early polluters of water sources too. As the Industrial Revolution progressed, water pollution became a major crisis. Factories found water sources, especially rivers, a convenient means of waste disposal. The trend continued well into the twentieth century. The Cuyahoga River in Ohio caught fire several times since the 1930s, a result of oil slicks and flammable industrial waste dumped in it. Coupled with widespread and human waste contamination of rivers, a fire on the Cuyahoga in 1969, led to the enactment of the 1972 Clean Water Act (CWA). The CWA prohibits pollutants' discharge into navigable waterways, and there is no doubt it has improved water quality in the United States considerably. However, there is no realistic standard as to how clean is clean, and the act has been criticized for leading to wasted money without effective controls and monitoring systems. There is also the difficulty inherent in controlling nonpoint source pollution—pollution from diffuse or not-easily-identifiable sources—a harder task than controlling point source pollution, which can be predicted, controlled, and monitored.

The post–World War II era saw an explosion of industries and technological advances in developed nations, ranging from engineering to medicine. Many advances that occurred during wartime proved invaluable in peacetime. Antibiotics saved millions of lives, as did pesticides such as DDT, a compound that greatly reduced the incidence of typhus during the war, and later helped control malaria worldwide. But many industrial waste by-products found their way into the water, either through direct dumping by companies, or through leaching into groundwater from dumping sites. These by-products caused massive wildlife dieoffs, and are also blamed for elevated cancer rates, birth defects, and a lower IQ in people who subsisted on water polluted by heavy industries.

In 1962 scientist Rachel Carson wrote *Silent Spring*, an explosive exposé condemning the use of long-lasting pesticides in general, and DDT in particular. Her carefully researched material and its masterful presentation were the driving forces behind the emerging environmental movement in the United States and around the world. The book focused attention on the problem of pollution in the environment. It is believed that many pollution

control laws, including CWA, were influenced by *Silent Spring*. The use of DDT in many nations was subsequently banned. Globally, DDT is currently approved only for control of insect-borne diseases such as malaria, while safer alternatives are being researched.

Air Pollution

The growth of population centers coupled with the switch from wood-burning to coal-burning fires created clouds of smoke over cities as early as the eleventh century. Air pollution regulations first appeared in England in 1273, but for the next several centuries, attempts at controlling the burning of coal met with notable failure. The problem was not confined to London, nor was it confined to England. As the Industrial Revolution swept across countries, and as coal became common in private residences, smoke and industrial pollution claimed more and more lives. In the United States, Donora, Pennsylvania, became famous for a tragedy that symbolized the dangers of industrial air pollution. On October 26, 1948, a thick, malodorous fog enveloped the small industrial town. Unlike usual fogs, it did not burn off as the day progressed. Instead, it stayed on the ground for five days. Twenty people died in Donora and 7,000 were hospitalized with respiratory problems. The cause was a weather anomaly that trapped toxic waste emissions from the town's zinc smelting plant close to the ground. The Donora disaster brought air pollution into focus in the United States, and paved the way for the Clean Air Act, enacted in 1963 and strengthened in 1970.

Between December 5 and 9, 1952, 4,000 people died in London as a result of smog trapped in a thermal inversion (a condition where the air close to the ground is colder than the layer above it, and is therefore unable to rise above it). This incident brought about England's Clean Air Act in 1956.

Smoke from coal-fired power plants creates the related problem of acid rain. Gases (sulfur dioxide and nitrogen oxides) released by burning fossil fuels make the rain more acidic and therefore corrosive. Acid rain kills plants and trees and damages structures. It also accumulates in rivers and streams, and has resulted in lakes that are already devoid of life in large parts of eastern North America and Scandinavia.

All around the world, the advent of the internal combustion engine-powered vehicles compounded air pollution, adding particulate and gaseous contaminate to the air people breath. The use of leaded gasoline raised lead levels in populations around the world. Leaded gasoline was phased out in the U.S. starting in 1976, but is still in use in many parts of the world In 1987, scientists discovered a hole in the ozone layer and recognized a serious threat to the layer that protects the earth from the sun's ultraviolet radiation. The Montréal Protocol, drafted in 1987, addressed the damage caused to the ozone layer by a chemical group known as CFCs, which were common in aerosol spray containers and air conditioners. The Montréal Protocol set as a goal the elimination of CFCs in consumer and industrial products. The global climate change accord signed in Rio de Janeiro, Brazil, in 1992 addressed the so-called "greenhouse gases," gases which trap heat in the atmosphere and lead to a global warming trend. The Rio Accord, and the Kyoto Protocol (1997) call for a reduction in greenhouse gases emissions but little progress has been made as the United States, a major generator of greenhouse gases, never signed the treaty and President George W. Bush has rejected the Kyoto Protocol outright.

Woman planting flowers in New York's Union Square Park on the first Earth Day. (©Bettmann/Corbis. Reproduced by permission.)

Land Pollution

At the beginning of the twentieth century, William T. Love imagined a model community in New York, on the edge of Niagara Falls. Love dug a canal to supply water power to what he envisioned would be a combination of industrial and residential areas in his community.

Love was unable to complete his project. During the 1920s the canal he dug was turned into a landfill operated by the Hooker Chemical Company. In 1953 Hooker sold the site to the Niagara Falls Board of Education for $1, with the disclaimer "...that the premises above described have been filled ... to the present grade level thereof with waste products resulting from the manufacturing of chemicals. ..." The city built an elementary school on the site. Houses were later added. Over the years, the underground containers filled with approximately 21,000 tons of chemical waste corroded. In 1977 a record rainfall brought about a tragic consequence: The waste began to leach into people's homes, backyards, and playgrounds. Love Canal has been officially associated with high rates of birth defects, miscarriages, and other severe illness resulting from land contamination.

The tragedy of Love Canal is perhaps the most famous incident of chemical waste dumps harming people, but it is definitely not the only one. Health effects range from cancer to birth defects. The practice of chemical dumping persisted for years in the early twentieth century, in many places, without a thought to the possible risks or consequences of these actions. When Love Canal leached its deadly contents, the United States took notice. In 1980 Congress enacted the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the first U.S. federal law to address toxic waste dumps. CERCLA, also known as Superfund, is the emergency fund to clean toxic waste dumps when the owners of the dumps are unknown or unable to pay for a necessary cleanup. While Superfund is helping clean up many hazardous sites, litigation over liability led to delay and costly legal battles over who pays for cleanups. Another criticism is that Superfund lacks clear standards as to what constitutes a “clean” site.

Across the globe, developing countries have been buying hazardous waste from developed nations, where disposal is more expensive. Historically, there has been little or no regulation of hazardous waste disposal in developing nations; as the world becomes more of a global community, however, this problem will no doubt haunt future generations.

Chemical Pollution

In 1984, 30 tons of lethal methyl isocyanate gas were released into the air in Bhopal, India, from a Union Carbide plant. Thousands of people (estimates range from 2,500 to well over 8,000) died immediately. Deaths and disabilities continued to plague the populace for years following what was termed, at the time, “the worst industrial accident in history.” A year later, in Institute, West Virginia, another Union Carbide plant released toxic gas into the atmosphere, resulting in illnesses among town residents. Deeply concerned about the possibility of a Bhopal-like disaster in the United States, Congress acted swiftly to enact the Emergency Planning and Community Right-to-Know Act (EPCRA). The law requires companies that handle hazardous waste to furnish complete disclosure of their annual polluting activities, storage and handling facilities, any accidental release of hazardous material into the environment in a quantity above an established safe limit, and all material necessary for local authorities to respond to an accident involving the hazardous material(s) on site. Since the law was enacted, a substantial reduction in toxic releases was reported by companies who are required to participate in EPCRA disclosures.

Oil pollutes land and water sources, the most tragic example of which is the *Exxon Valdez.* While not one of the largest spills in the world, it is considered the worst in terms of the damage to the environment. On the night of March 24, 1989, the oil tanker ran aground at Bligh Reef, Alaska, spilling eleven million gallons of oil into the fragile environment of Prince William Sound. A lack of containment and cleanup equipment compounded the problem, and even fifteen years after the spill the Prince William Sound environment was still struggling to recover from the massive damage.

One response to the *Valdez* disaster was the passage of the 1990 Oil Pollution Act, which, among other things, required oil tankers to be double-hulled, and gave states more say in their spill-prevention standards. The spill-response equipment and safeguards procedures at Prince William

Residents of Bhopal, India, standing outside the gate of the Union Carbide factory where a chemical leak killed thousands and blinded many others. (©Bettmann/Corbis. Reproduced by permission.)

Sound, loading terminal for the major tanker route on the Trans-Alaska Pipeline System, have been brought up to date.

Nuclear power is one of the most controversial issues of our time. For many people, the benefits it brings are dwarfed by the immense dangers inherent in the nature of its fuel. Release of radioactivity into the air and the atmosphere occurred over the years, but accidents like Chernobyl and Three Mile Island terrify people, and with good reason.

On March 28, 1979, a partial meltdown of the reactor in Three Mile Island, Pennsylvania, released radioactivity into the atmosphere. The release itself was small, according to authorities. But inside the containment building a hydrogen bubble was growing, threatening to blow the building and spew radioactivity into an area inhabited by some 300,000 people. The effects such an explosion would have had on the population were only theorized until 1986, when the nuclear reactor in Chernobyl, Ukraine, did explode. Though the immediate loss of life was small according to official figures, within several months the death toll was growing. Cancer rates, especially in children, have soared in the Ukraine and Belarus. And while the blown reactor is buried in concrete, evidence show the cover is deteriorating.

The Three Mile Island accident led to the establishment of the Institute of Nuclear Power Operations (INPO). INPO is tasked with promoting safety in commercial nuclear plants in the United States, and cooperates with similar international organizations.

While safety regulations and oversight bodies were upgraded and tightened as a result of the two accidents above, nuclear waste, both civilian and military, presents a huge problem of disposal. The decay of some nuclear waste can take thousands of years. Disposal of the short-lived waste is easy compared to finding a place that can safely store highly radioactive materials for thousands of years. Moreover, many communities oppose the transportation and/or burial of such waste in their area.

Environmental pollution is not new, but its scope, type, and complexity have worsened since World War II. The good news is that nations across the globe now have an awareness of the consequences of pollution, and the dangers they pose to our very existence. Both governments and nongovernmental organizations are working on the many facets of pollution. Among the answers they seek are alternative, nonpolluting energy sources, a way to control harmful emissions and toxic discharges into the air and water, and methods for cleaning up damaged ecosystems and bringing species back from the brink of extinction. Coincident with this work is the growing understanding that a safe and protected environment must begin with social healing, that both poverty and affluence perpetuate environmental degradation. Poor societies must concentrate on immediate survival before they can spare the time or energy to worry about environmental health. Rich societies must understand that their comfortable lifestyle comes at the high price of increased pollution—from sources such as factories, car engines, and power plants. The challenges that face the global community as it tries to combat an ecological crisis involve creating social conditions that allow all members of the community to be equally committed to, and equally capable of, healing the place we all call home. SEE ALSO CARSON, RACHEL; CLEAN AIR ACT; CLEAN WATER ACT; DISASTERS: CHEMICAL ACCIDENTS AND SPILLS; DISASTERS: NUCLEAR ACCIDENTS; DISASTERS: OIL SPILLS; DONORA, PENNSYLVANIA; EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW; ENVIRONMENTAL MOVEMENT; LAWS AND REGULATIONS, INTERNATIONAL; LAWS AND REGULATIONS, UNITED STATES; MASS MEDIA; SUPERFUND.

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Adi R. Ferrara

Hospital Waste *See Medical Waste*

Household Pollutants

Household pollutants are contaminants that are released during the use of various products in daily life. Studies indicate that indoor air quality is far worse than that outdoors because homes, for energy efficiency, are made somewhat airtight. Moreover, household pollutants are trapped in houses causing further deterioration of indoor air quality.

Hazardous household products fall into six broad categories: household cleaners, paints and solvents, lawn and garden care, automotive products, pool chemicals, and health and beauty aids. Many commonly used household products in these categories release toxic chemicals. As an alternative, manufacturers are introducing products, often referred to as green products, whose manufacture, use, and disposal do not become a burden on the environment.

Chemicals in Household Products and Their Effects

Many household products like detergents, furniture polish, disinfectants, deodorizers, paints, stain removers, and even cosmetics release chemicals that may be harmful to human health as well as cause environmental concerns (see the table, "Household Products and Their Potential Health Effects"). Insecticides, pesticides, weed killers, and fertilizers that are used for maintaining one's lawn and garden are another source of household pollution. Their entry into the house could occur through air movement or adsorption by shoes and toys, which are then brought inside the house.

A common class of pollutants emitted from household products is volatile organic compounds (VOCs). Sources for these pollutants include paint strippers and other solvents, wood preservatives, air fresheners, automotive products, and dry cleaned clothing. Formaldehyde is a major organic pollutant emitted from pressed wood products and furniture made from them, foam insulation, other textiles, and glues. Exposure to very high concentrations of formaldehyde may lead to death.

Other household products that contain harmful chemicals are antifreeze, car cleaners and waxes, chemicals used in photo development, mice and rat poison, rug cleaners, nail polish, insect sprays, and wet cell batteries. Such household chemicals may pose serious health risks if not handled, stored, and disposed of properly.

Indoor Air Pollutants from Other Household Activities

From time to time, homeowners complete a variety of remodeling projects to improve the aesthetic look of their house. These include new flooring, basement remodeling, hanging new cabinets, removing asbestos sheets, scraping off old paint (which might contain lead), and the removal or application of wallpaper. Such activities could be a significant source of indoor air pollutants during and after the project. Asbestos, formaldehyde, benzene, xylene, toluene, chloroform, trichloroethane and other organic solvents, and lead dust are the main pollutants released during remodeling. Homes built before 1970s may pose additional environmental problems because of the use of lead- and asbestos-containing materials. The use of both materials was common in

HOUSEHOLD PRODUCTS AND THEIR POTENTIAL HEALTH EFFECTS

Product Type	Harmful Ingredients	Potential Health Hazards
Air fresheners & deodorizers	Formaldehyde	Toxic in nature; carcinogen; irritates eyes, nose,throat and skin; nervous, digestive, respiratory system damage
Bleach	Sodium hypochlorite	Corrosive; irritates and burns skin and eyes; nervous, respiratory, digestive system damage
Disinfectants	Sodium hypochlorite	Corrosive; irritates and burns skin and eyes; nervous, respiratory, digestive system damage
	Phenols	Ignitable; very toxic in nature; respiratory and circulatory system damage
	Ammonia	Toxic in nature; vapor irritates skin, eyes and respiratory tract
Drain cleaner	Sodium/potassium hydroxide (lye)	Corrosive; burns skin and eyes; toxic in nature; nervous, digestive and urinary system damage
Flea powder	Carbaryl	Very toxic in nature; irritates skin; causes nervous, respiratory and circulatory system damage
	Dichlorophene	Toxic in nature; irritates skin; causes nervous and digestive system damage
	Chlordane and other chlorinated hydrocarbons	Toxic in nature; irritates eyes and skin; cause respiratory, digestive and urinary system damage
Floor cleaner/wax	Diethylene glycol	Toxic in nature; causes nervous, digestive and urinary system damage
	Petroleum solvents	Highly ignitable; carcinogenic; irritate skin, eyes, throat, nose and lungs
	Ammonia	Toxic in nature; vapor irritates skin, eyes and respiratory tract
Furniture polish	Petroleum distillates or mineral spirits	Highly ignitable; toxic in nature; carcinogen; irritate skin, eyes, nose, throat and lungs
Oven cleaner	Sodium/potassium hydroxide (lye)	Corrosive; burns skin, eyes; toxic in nature; causes nervous and digestive system damage
Paint thinner	Chlorinated aliphatic hydrocarbons	Toxic in nature; cause digestive and urinary system damage
	Esters	Toxic in nature; irritate eyes, nose and throat
	Alcohols	Ignitable; cause nervous system damage; irritate eyes, nose and throat
	Chlorinated aromatic hydrocarbons	Ignitable; toxic in nature; digestive system damage
	Ketones	Ignitable; toxic in nature; respiratory system damage
Paints	Aromatic hydrocarbon thinners	Ignitable; toxic in nature; carcinogenic; irritates skin, eyes, nose and throat; respiratory system damage
	Mineral spirits	Highly ignitable; toxic in nature; irritates skin, eyes, nose and throat; respiratory system damage
Pool sanitizers	Calcium hypochlorite	Corrosive; irritates skin, eyes, and throat; if ingested cause severe burns to the digestive tract
	Ethylene (algaecides)	Irritation of eyes, mucous membrane and skin; effects reproductive system; probable human carcinogen of medium carcinogenic hazard
Toilet bowl cleaner	Sodium acid sulfate or oxalate or hypochloric acid	Corrosive; toxic in nature; burns skin; causes digestive and respiratory system damage
	Chlorinated phenols	Ignitable; very toxic in nature; cause respiratory and circulatory system damage
Window cleaners	Diethylene glycol	Toxic in nature; cause nervous, urinary and digestive system damage
	Ammonia	Toxic in nature; vapor irritates skin, eyes and respiratory tract

SOURCE: Compiled by author.

ALTERNATIVES TO COMMON HOUSEHOLD PRODUCTS

Product	Alternative(s)
Air refresher	Open windows to ventilate. To scent air, use herbal bouquets, pure vanilla on a cotton ball, or simmer cinnamon and cloves.
All-purpose cleaner	Mix ⅔ cup baking soda, ¼ cup ammonia and ¼ cup vinegar in a gallon of hot water. Doubling all the ingredients except the water can make stronger solution.
Brass polish	Use paste made from equal parts vinegar, salt and flour. Be sure to rinse completely afterward to prevent corrosion.
Carpet/rug cleaner	Sprinkle cornstarch/baking soda on carpets and vacuum.
Dishwashing liquid	Wash dishes with hand using a liquid soap or a mild detergent.
Drain opener	Add 1 tablespoon baking soda into drain and then slowly pour ⅓ cup white vinegar to loosen clogs. Use a plunger to get rid of the loosened clog. Prevent clogs by pouring boiling water down drains once a week, using drain strainers, and not pouring grease down drains.
Fabric softener	Use ¼ to ½ cup of baking soda during rinse cycle.
Fertilizer	Use compost and organic fertilizers.
Floor cleaner	Mix 1 cup vinegar in 2 gallons of water. For unfinished wood floors, add 1 cup linseed oil. To remove wax buildup, scrub in club soda, let soak and wipe clean.
Floor polish	Polish floors with club soda.
Furniture polish	Mix 1 teaspoon lemon oil and 1 pint mineral oil. Also, use damp rag.
Insecticides	Wipe houseplant leaves with soapy water.
Laundry bleach	Use borax on all clothes or ½ cup white vinegar in rinse water to brighten dark clothing. Nonchlorinated bleach also works well.
Methylene chloride paint stripper	Use nontoxic products.
Mothballs	Place cedar chips or blocks in closets and drawers.
Oil-based paint, thinner	Use water-based products.
Oven cleaner	Wash the oven with a mixture of warm water and baking soda. Soften burned-on spills by placing a small pan of ammonia in the oven overnight. Sprinkle salt onto fresh grease spills and then wipe clean.
Pesticide	Use physical and biological controls.
Silver cleaner	Add 1 teaspoon baking soda, 1 teaspoon salt and a 2" x 2" piece of aluminum foil to a small pan of warm water. Soak silverware overnight.
Toilet cleaner	Use baking soda, a mild detergent, and a toilet brush.
Window cleaner	Mix ¼ cup ammonia with 1 quart water.

SOURCE: Based on information available from various sources including the Web site of Air and Waste Management Association

building construction prior to the 1970s (e.g., lead-based paint used to paint homes).

Avoiding Exposure and the Use of Green Products

There are several steps one can take to reduce exposure to household chemicals. An adjacent table provides a list of alternative products. One can bring unused and potentially harmful household products to a nearby chemical

TOXIC RELEASES FROM CARPET

The styrene-butadiene (SB) latex backing that is used on most new carpets is a source of styrene and 4-phenyl cyclohexene (4-PC). Styrene is a known toxic and suspected carcinogen. 4-PC is not known to be toxic, and it continues to be emitted at measurable levels for a longer time because it is also less volatile. Vinyl-backed carpets emit an entirely different set of chemicals, notably vinyl acetate and formaldehyde. Health complaints associated with carpets include severe neurological and respiratory problems; health problems usually arise more frequently in individuals with multiple chemical sensitivities or **sick building syndrome.** Carpet material may not be the largest contributor to indoor air quality problems after a new carpet has been installed. Studies indicate that carpet adhesives and seam sealants emit far more pollutants, especially in the first seventy two hours after installation. Carpet cushions, or pads, may be at fault as well. The majority of adhesives are based on SB latex and generally the most significant short-term source of VOC emissions. Since 1991, adhesive manufacturers have been actively researching ways to reduce solvent levels even further, and by 2002 some claimed a calculated VOC level of zero. Seam sealants, another major culprit, release known toxins, including toluene and 1,1,1-trichloroethane.

sick building syndrome shared health and/or comfort effects apparently related to occupation of a particular building

collection center; many communities have such a center. Chemicals received at these centers are recycled, disposed of, or offered for reuse. One may also purchase just the amount needed or share what is left over with friends. In addition, one should always avoid mixing different household chemicals.

Most of the chemicals released during remodeling projects are toxic in nature, and some of them are even carcinogenic. Proper care, such as employing wet methods for suppressing dust, use of high-efficiency filters to collect fine particulates, and sealing the remodeling area, must be taken while remodeling to prevent the emission of harmful chemicals into the surrounding air. Reducing material use will result in fewer emissions and also less waste from remodeling operations. Another good practice is to use low-environmental-impact materials, and materials produced from waste or recycled materials, or materials salvaged from other uses. It is important to avoid materials made from toxic or hazardous constituents (e.g., benzene or arsenic).

Indoor air quality should improve with increasing consumer preference for green products or low-emission products and building materials. Green products for household use include products that are used on a daily basis, such as laundry detergents, cleaning fluids, window cleaners, cosmetics, aerosol sprays, fertilizers, and pesticides. Generally, these products do not contain chemicals that cause environmental pollution problems, or have lesser quantities of them than their counterparts. Some chemicals have been totally eliminated from use in household products due to strict regulations. Examples include the ban of phosphate-based detergents and aerosols containing chlorofluorocarbons. A list of green products available in the United States and other countries is provided in an adjacent table. Materials like plaster boards, urea-formaldehyde foam insulation, soldering glue, switches, and panel boards, which are known to cause indoor air quality problems, have been substituted with other eco-friendly products, which serve the same purpose but have low emissions. SEE ALSO Asbestos; Chemistry, Green;

COMMONLY AVAILABLE GREEN PRODUCTS

Nontoxic skin care products
Odor-controlling equipment
Composting toilets
Natural pesticides
Nontoxic pet care products
Unleaded gasoline
Low-emission products
Paints and varnishes
Organic food products
Air cleaning equipment
Pest control equipment
Nontoxic cleaning products
Organic gardening supplies
Recycled products
Jute, coir, and woolen carpets
Energy-efficient appliances

Note: All products are not available in all countries

SOURCE: Compiled by author.

INDOOR AIR POLLUTION; LEAD; PESTICIDES; RECYCLING; REUSE; VOCS (VOLATILE ORGANIC COMPOUNDS).

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Ashok Kumar and Rishi Kumar

Hypoxia

Hypoxia is a drastic reduction in the amount of oxygen dissolved in water—a state that can be fatal to fish and other gill-breathing animals. Hypoxia is most often caused by pollution from nitrogen and phosphorus compounds derived from fertilizers, animal waste, sewage, or atmospheric contaminants. The pollutants stimulate an excessive growth of plant material. When these plants—typically algae—die and decay, they support large populations of bacteria, which take oxygen from the water. Pollution with sewage solids has a similar effect. Prevention involves controlling the sources of pollution by improved agricultural practices, treatment of sewage, and, to a lesser extent, reduction of emissions from the burning of fossil fuels. SEE ALSO FISH KILLS; WASTEWATER TREATMENT; WATER POLLUTION.

Kenneth H. Mann

I

Incineration

Incineration is the thermal destruction of waste. It is as old as throwing food wastes on a wood fire, and in many developing nations, garbage is still routinely burned in drums and boxes on city streets. Modern incineration systems use high temperatures, controlled air, and excellent mixing to change the chemical, physical, or biological character or composition of waste materials. The new systems are equipped with state-of-the-art air pollution control devices to capture particulate and gaseous emission contaminates. There are still many health concerns connected with incineration systems, especially for populations living near incinerators. However, the stringent regulations that have been enacted by federal and state regulators ensure that the design, operation, testing, and maintenance of these systems provide maximum safety and minimum risk to the surrounding area and inhabitants.

In 1992 the United States had 190 operating incinerators with a design capacity of 114,339 tons/day and an annual capacity of 35.5 million tons. Germany, which has the highest concentration of incinerators in Europe, has 53 units with an annual capacity of 10.7 million tons.

Incineration can be adapted to the destruction of a wide variety of wastes. This includes but is not limited to household wastes, often referred to as

municipal wastes, industrial wastes, medical wastes, sewage, Superfund soils and liquids, and the hazardous wastes (liquids, tars, sludges, solids, and vent fumes) generated by industry. Unlike many other methods of waste disposal, incineration is a permanent solution. The major benefit of incineration is that the process actually destroys most of the waste rather than just disposing of or storing it.

Many local community incinerators were built after World War II. The suburban communities surrounding large urban centers selected incineration as the method of disposal over landfills. There was a lack of consideration of exhaust emissions from these units in the original designs: Tall stacks were used for dispersion rather than proper air pollution controls. The combustion furnaces operated at high excess air levels resulting in lower temperatures, incomplete combustion and high levels of carbon monoxide and unburned hydrocarbons. Typical conditions surrounding these facilities were high soot and odor levels as well as corrosion from acid gas deposition. It was an unhealthy and unsafe environment for the neighbors.

This created the well-known NIMBY syndrome—"Not in My Backyard." In the 1960s and 1970s, more units were shut down than planned for new construction. The Resource Recovery Act (RRA) was passed in 1965, followed by the Clean Air Act (CAA) in 1970, the Resource Conservation and Recovery Act (RCRA) in 1976, the Hazardous and Solid Wastes Amendments (HSWA) in 1984, and the Maximum Achievable Control Act (MACT) in 1999. New and existing systems require the proper controls for combustion and air pollution control to receive a construction, retrofit, and operating permit. This has reduced the past concerns about health and the environment surrounding these facilities. Incinerator regulations in the twenty-first century are considered the most stringent of all types of combustion and energy recovery systems. They are also the most protective for the health and environment of local communities.

Combustion

Waste incineration involves the application of combustion processes under controlled conditions to convert waste materials to inert mineral ash and gases. The three Ts of combustion (temperature, turbulence, and residence time) must be present along with sufficient oxygen for the reaction to occur:

- The burning mixture (air, wastes, and fuel) must be raised to a sufficient temperature to destroy all organic components. The combustion airflow is reduced to the minimum level needed to provide the oxygen for the support fuel (gas, oil, or coal) and the combustible wastes without forming high levels of CO and unburned hydrocarbons. This will raise the temperature to the level needed for good combustion.
- Turbulence refers to the constant mixing of fuel, waste, and oxygen.
- Residence time is the time of exposure to combustion temperatures.
- Oxygen must be available in the combustion zone.

Types of Incinerators

Waste incinerators are used to destroy solids, sludges, liquids, and tars. Depending upon the physical, chemical characteristics of the waste and the

handling they require, different incinerator designs will be applied. Solids, sludges, and tars are incinerated in fixed-hearth and rotary kiln incinerators. Liquids may also be burned in these systems and used as support fuel. In many plants where liquids are the primary wastes, liquid injection incinerators are used. Boilers, process furnaces, cement kilns, and lightweight aggregate kilns also utilize the energy available from liquid wastes and burn liquid wastes as well as the fossil fuels (natural gas and oil).

Fixed-Hearth Incinerators. Fixed-hearth incinerators are used extensively for medical and municipal waste incineration. Fixed hearths can handle bulk solids and liquids. A controlled flow of "underfire" combustion air (70 to 80 percent of the theoretical air required) is introduced up through the hearth on which the waste sits. Bottom ash is removed by dumping into a water bath.

Unburned combustibles and high levels of carbon monoxide and hydrogen exit above the hearth. These volatiles are oxidized in the combustion zone where overfire air provides sufficient excess air and residence time at temperature to ensure complete burnout. The three Ts of combustion and oxygen provide high combustion efficiency. Natural gas or oil is supplied to maintain temperatures as high as 2,000°F. In some large municipal waste combustors, called waste-to-energy plants, heat recovery boilers are used to generate steam for electric generation. These plants are also referred to as trash-to-steam plants. All incinerator systems are now regulated by exhaust emissions. Air pollution control systems are installed to control emissions of particulate matter including metals and ash, hydrocarbons including dioxins and furans, and acid gases created from the combustion of wastes containing chlorine, sulfur, phosphorous, and nitrogen compounds.

Rotary Kiln Incineration. Solid wastes as well as liquid wastes generated by industry are destroyed by on-site and commercial-site rotary kiln incinerator systems. The rotary kiln is a cylindrical **refractory**-lined shell that is rotated to provide a tumbling and lifting action to the solid waste materials. This exposes the waste surface to the flames from fuel burning as well as liquid waste burning in the rotating kiln. Flames will also be generated over the surface of waste solids exposed to the heat and incoming air. Pumpable sludges and slurries are injected into the kiln through nozzles. Temperatures for burning vary from 1,300 to 2,400°F. Lower temperatures are often necessary to prevent slagging of certain waste materials.

refractory resistant (to heat: difficult to melt; also to authority)

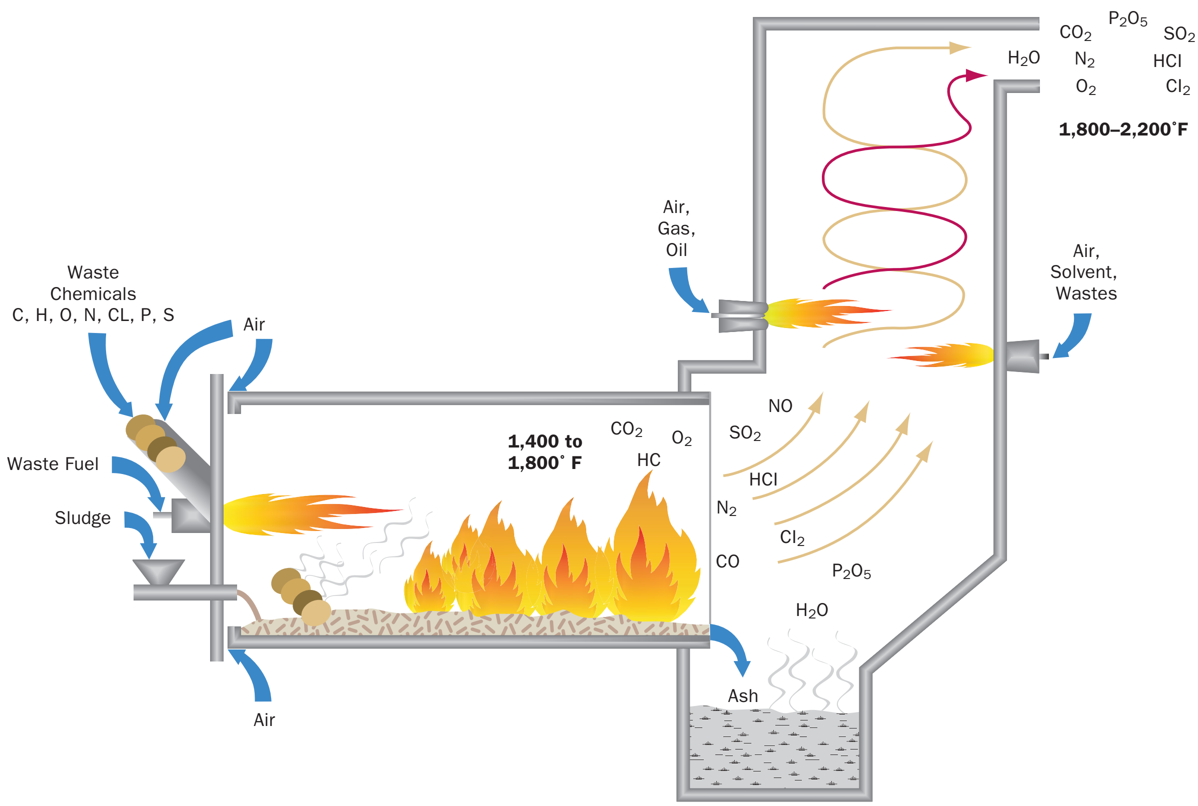
The rotary kiln provides excellent mixing through a rotating-tumbling action that distributes heat evenly to all the waste materials contained within it. The kiln is the primary combustion chamber (PCC) where organic compounds in the wastes are **volatilized** and **oxidized** as air is introduced into the kiln. The unburned volatiles enter the secondary combustion chamber (SCC) along with the hot products of combustion from the PCC where additional oxygen is introduced and ignitable liquid wastes or fuel can be burned. Complete combustion of the volatized waste from the PCC, liquid wastes and fuel occurs in the SCC.

volatilize vaporize; become gaseous

oxidize react with oxygen

Liquid Injection. The chemical industries generate liquid wastes that contain toxic organics. Typical wastes from the agricultural and pharmaceutical plants may contain compounds such as chlorinated benzenes, vinyl chloride, toluene, phosphorous, and naphthalene. On-site liquid injection incinerators are used to destroy these wastes. Liquid injection incinerators are refractory-

ROTARY KILN—AFTERBURNER



lined chambers, generally cylindrical in shape and equipped with a primary combustor and often secondary injection nozzles for high-water-content waste materials. The liquids are atomized through nozzles, exposed to high temperature fuel burner flames, vaporized, superheated, and when combined with air in a turbulent zone attain temperature levels from 1,800 to 3,000°F. Residence time in the chamber is based on the flow volume of these combined products of combustion (fuel, air, and liquid wastes) in actual cubic feet per second. The physical volume of the chamber in cubic feet determines the total time of these gases in the chamber. This time may vary from 0.5 seconds up to 2.5 seconds. The toxic organic components of the liquid waste are oxidized to carbon dioxide, water vapor, oxygen, nitrogen, and acid gases. Acid gases formed are cleaned from the exhaust stream by wet **scrubbers**, thus allowing clean products to leave the exhaust stack. Incineration has resulted in the ultimate answer to the disposal of these waste materials.

scrubber an air pollution control device that uses a spray of water or reactant or a dry process to trap pollutants in emissions

Emission-Control Systems

A great amount of effort has gone into the proper design of air pollution control systems associated with incinerators. Most liquid injection incinerators generate acid gases: hydrogen chloride, sulfur oxides, nitrogen oxides, and others. A proper scrubber is required for the absorption of acid gases.

In systems burning solid and liquid wastes, the wastes may contain toxic metals such as arsenic, beryllium, cadmium, chromium, lead, and mercury.

COMPARISON OF AIR POLLUTION CONTROL SYSTEM COMPONENTS

Parameter/ Components	SDA[a]	Venturi	Packed Bed	Dry ESP[b]
Particulate Removal	Poor to Fair	Good	Poor	Excellent
Heavy Metal Removal	Excellent[c]	Good	Poor	Good
Acid Gas Removal	Good to Exc.	Good	Excellent	Poor
Residue	Fly Ash	Scrub Liquor	Scrub Liquor	Flyash
Auxiliary Equipment Needed	Baghouse Ash Handling	Demister Liquid S&T[d]	Demister Liquid S&T	Ash Handling
Turndown	3:1	2:1	5:1	5:1
Plume Suppression	Easy	Difficult	Difficult	Easy
Pressure Drop	Low	High	Moderate	Low
Capital Cost	Moderate	Low	Low	High

[a]Spray Dryer absorber
[b]Electrostatic Precipitator
[c]When used with a baghouse or ESP
[d]Storage and Treatment

spray dryers dryer used to remove heavy metals and other pollutants from incineration gases

baghouse large fabric bag, usually made of glass fibers, used to eliminate intermediate and large particles

Particulates that form may be submicron in size and carried in the combustion gases. These particulates are removed in high-efficiency scrubbers. Wet scrubbers are also used to neutralize acid gases formed from burning wastes containing chlorine, sulfur, phosphorous, and nitrogen compounds. Dry scrubbers are typically bag filters. Most recent larger systems incorporate **spray dryers** for acid-gas removal followed by **baghouses** for ash-particulate removal. When wet packed tower absorber scrubbers are used for HCl, SO_x, and NO_x scrubbing, a lean acid solution is generated that is then delivered to a lagoon for neutralization with caustic or lime solutions prior to discharge to the plant's wastewater treatment system. See the table for a comparison of scrubber types used for waste incineration. SEE ALSO Hazardous Waste; Medical Waste; Solid Waste; Waste to Energy.

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Joseph J. Santoleri

Indoor Air Pollution

Indoor air pollution is the presence of one or more contaminants indoors that carry a certain degree of human health risk. Indoor air issues may be traced to the beginning of civilization. Prehistoric records note the problem of smoke in caves. However, over the last three decades the public has become more aware of indoor air pollution. Various studies show that people spend 65 to 90 percent of their time indoors; 65 percent of that time is spent at home. Field studies of human exposure to air pollutants indicate that indoor air levels of many pollutants may be two to five times, and on occasion more than one hundred times, higher than outdoor levels.

MAJOR INDOOR AIR POLLUTANTS, SOURCES, HEALTH EFFECTS AND CONTROL

Pollutants	Sources	Health Effects	What To Do
By-products of combustion (such as CO, CO_2, NO_x)	Unvented kerosene and gas heaters, gas appliances, wood- and gas-burning fireplaces, leaking chimneys and furnaces, tobacco smoke, automobile exhaust in attached garages	Eye, nose, and throat irritation, impaired lung function and respiratory function in children, bronchitis, lung cancer, flu-like symptoms.	1. Avoid use of unvented gas or kerosene space heaters 2. Keep gas appliances and furnaces properly adjusted 3. Install and use exhaust fans 4. Change filters on heating/ cooling systems and air cleaners 5. Increase of supply of outside air 6. Proper location of air intakes to avoid exhaust from vehicles
Environmental tobacco smoke	Cigarettes, cigars, pipes	Eye, nose, and throat irritation, headaches, pneumonia. Increased risk of respiratory and ear infections in children. Lung cancer and increased risk of heart disease.	1. Stop smoking 2. Discourage others from smoking 3. Isolate smokers outdoors
Formaldehyde	Pressed wood products (hardwood, plywood wall paneling, particleboard, fiberboard) used in buildings and furniture, urea-formaldehyde foam insulation, permanent press textiles, glue, ETS, vehicle exhaust, stoves, fireplaces	Eye, nose, and throat irritation, coughing, fatigue, rashes, and allergic reactions. Causes cancer in animals. Death at very high concentration.	1. Use products with lower emission rates of formaldehyde 2. Keep humidity low in house 3. Increase ventilation 4. Aging or baking of products
Other volatile organic compounds	Paints, solvents, wood preservatives, aerosol sprays, cleaners and disinfectants, moth repellents, air fresheners, hobby supplies, and dry cleaned clothes	Eye, nose, and throat irritation, headaches, loss of coordination; nausea, damage to kidney and central nervous system. Some cause cancer in animals. Some may cause cancer in humans.	1. Buy only what you need 2. Read labels and follow instructions 3. Use in well-ventilated areas or outdoors 4. Hang dry cleaned clothes in an open area for about 6 hours.
Radon	Local geology, soil, water	Lung cancer, possibility of stomach cancer	1. Seal cracks and openings in the basement 2. Ventilate crawl space 3. Subslab suction 4. Increase ventilation
Pesticides	Garden and lawn chemicals, poisons for pest control	Eye, nose, and throat irritation, damage to central nervous system and kidney, cancer	1. Use nonchemicals if possible 2. Avoid storage in the house 3. Follow manufacturer's instructions 4. Increase ventilation
Asbestos	Deteriorating or damaged insulation, fireproofing, or acoustical materials	Cancer and lung diseases (smokers at higher risk)	1. Test the suspected material 2. Remove asbestos by a trained contractor or develop a maintenance plan 3. Encapsulation of material containing asbestos
Heavy metals	Paints, automobiles, tobacco smoke, soil, and dust	Headaches, irritation in mouth, rash, excessive perspiration, kidney damage	1. Vacuum regularly 2. Removal of lead based paint
Bioaerosols	Humans, pets, moist surfaces, humidifiers, ventilation systems, drip pans, cooling coils in air handling units, plants, outside air	Legionnaires' disease, humidifier fever, influenza	1. Remove the source 2. Maintenance of equipment 3. Humidity control to 40% to 60% 4. Use of filters in ventilation 5. Air cleaning by the use of disinfectants

SOURCE: Adapted from U.S. Environmental Protection Agency and Consumer Product Safety Commission.

Sources of Indoor Pollution

There are various sources of indoor air pollutants in any building. A partial list of common sources is given in the table. Several types of combustion sources release inorganic gaseous pollutants, formaldehyde, suspended particulates that can be breathed, and other toxic chemicals. Tobacco products also release a mixture of over 4,000 compounds.

HEALTH SYMPTOMS ASSOCIATED WITH DIFFERENT ENVIRONMENTAL CONDITIONS

Environmental Condition(s)	Symptoms
• Ergonomic Conditions • Noise and Vibration	• Headache • Fatigue • Poor Concentration • Dizziness • Tiredness • Headache with nausea • Ringing in ears • Pounding heart
• Relative Humidity	• Dry throat • Shortness of breath or bronchial asthma • Irritation and infection of respiratory tract
• Relative Humidity • High Temperatures	• Nasal problems (stuffiness, irritation)
• Warm Air • Low Relative Humidity • Excessive Air Movement	• Skin problems (dryness, irritation, rashes)
• Artificial Light	• Eye problems (burning, dry gritty eye)

The pollutants released from building materials include formaldehyde, asbestos, and to a lesser extent radon. Formaldehyde is used in a variety of products, ranging from lipstick and shampoo to kitchen cabinets and carpeting, because it is an excellent preservative and bonding agent. Pressed wood products and furniture made with these products are found in offices and homes throughout the world. Urea-formaldehyde foam insulation is one of the major sources of formaldehyde. Asbestos, a known human **carcinogen**, is a mineral fiber that was widely used in a variety of building materials and as an insulating material and fire retardant in the United States until its use was banned in the early 1970s.

carcinogen any substance that can cause or aggravate cancer

Indoor radon problems generally result from the entry of radon gas released as a result of the radioactive decay of uranium found in soil around the house and in the geological formation under the foundation. Building materials such as granite, clay, bricks, rocks, sandstone, and concrete containing alum shale may also be major sources of radon, depending on their uranium content.

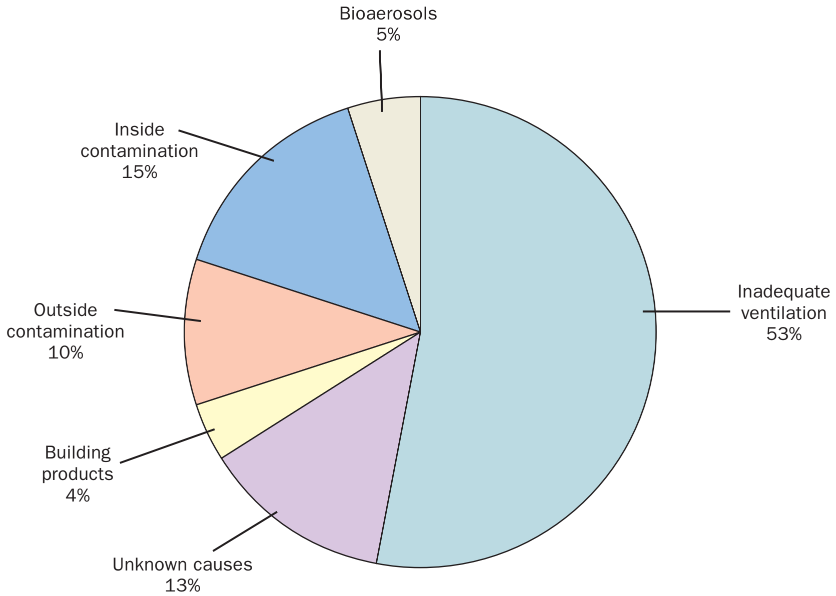
The pollutants released due to overcrowding of humans or animals include **bioaerosols**. Most of the bioaerosols present in the outdoors are induced indoors either by natural or mechanical intake of the ventilation systems. Humidifiers, air conditioning systems, cooling towers, mechanical ventilation systems, air-distribution ducts, and areas of water damage are the best breeding places for these bioaerosols. Pets are sources of saliva and dander.

bioaerosol very fine airborne particles produced by living organisms

Heavy metals such as lead, mercury, cadmium, and chromium have been found indoors. Their levels depend on the concentrations in outdoor air and the surrounding soil and dust. The residential use of lead paint was banned in the United States in 1978, decades after being outlawed in much of Europe because of the danger it posed to children. Residual lead paint is still present in many older buildings.

heavy metals metallic elements with high atomic weights; (e.g. mercury, chromium, cadmium, arsenic, and lead); can damage living things at low concentrations and tend to accumulate in the food chain

REASONS FOR INDOOR AIR QUALITY PROBLEMS



SOURCE: Adapted from the National Institute of Occupational Safety and Health.

Household products and personal care items are a constant source of indoor air pollution. Hobbies such as welding and soldering can easily add more pollutants to indoor environments. Office machines and domestic air cleaners are a major source of ozone.

Causes of Indoor Air Pollution

There are a variety of causes of poor indoor air quality. A NISOH study based on over five hundred complaints found that inadequate ventilation and the release of contaminants from indoor and outdoor sources are the primary reasons for indoor air quality problems (see pie chart). Inadequate ventilation may be defined as insufficient air to remove pollutants that are degrading the quality of air. Thus, the air quality in a building is the result of a contest between the pollutants and the ventilation system. Other factors that can aggravate this situation are temperature, humidity, and microbial contamination.

The early shutdown and late startup of a ventilation system and insufficient fresh outdoor air entering a ventilation system are often the direct result of overzealous energy-saving procedures. The problems of poor air distribution by a ventilation system within a building, limited air mixing in occupied areas, and clogged filters can contribute to poor air quality.

Since the early 1970s buildings have been built to be more airtight to conserve energy. This has resulted from using improved construction techniques and caulking and sealing. Unfortunately, this practice limits the amount of polluted air that escapes, which can cause pollutants to build up to unhealthy levels inside a building.

Temperature and humidity extremes can affect the emission rates of some pollutants as well as the perceptions of building occupants. High

Legionnaires' disease is a relatively rare type of pneumonia that is caused by *Legionella pneumophila,* a bacterium found primarily in warm-water environments. It was first identified when thirty-four people attending a 1976 American Legion convention in Philadelphia contracted the disease and died. The exact source of the outbreak is not known with certainty, but it is believed the bacterium was growing in an air conditioning tower on the roof of the old but well-maintained hotel where the conference was held. The disease is contracted by inhaling airborne water droplets containing *Legionellae.* It infects 10,000 to 15,000 persons annually in the United States and has a mortality rate of 20 to 50 percent.

humidity and high temperature cause people to feel lethargic and want more air movement. Low humidity induces coughing, dry throats, and dry eyes. An additional problem with low humidity is that it accentuates sense of smell. Noise from mechanical systems or glare from lights can cause headaches and fatigue. These are all symptoms of *sick building syndrome* and are thus usually blamed on poor air quality.

Health Effects of Indoor Air Pollutants

Health effects due to indoor air pollutants may be short- as well as long-term. Short-term problems include a stuffy, odorous environment and symptoms such as burning eyes, skin irritation, and headaches. Long-term health problems have a longer latency period or are chronic in nature. The magnitude and duration of detrimental health effects are influenced by the time of exposure, concentration, presence of a preexisting unhealthy condition, and age.

Health conditions involving some allergic reactions, including hypersensitivity pneumonitis, allergic rhinitis, and some types of asthma, are triggered by bioaerosols. Symptoms related to bioaerosols include sneezing, coughing, shortness of breath, fever, and dizziness. Infections such as influenza, measles, and chicken pox are also transmitted through the air. Overall, poor air quality may be responsible for a decrease in work performance, general feeling of poor health, reduced ability to concentrate, or illness.

Control of Indoor Air Pollution

Basic approaches to control indoor air pollution include source control, source isolation, increased ventilation, dehumidification, and the use of filters (see the table). Possible sources of contamination are eliminated in a source-control strategy. Examples include banning smoking in public buildings, using carefully selected building materials to avoid the emission of toxic or irritating substances, and limiting the use of fibrous materials. Source-isolation strategy is used in situations where a source cannot be completely eliminated. For instance, copy machine areas, food service stations, and bathrooms are often separately vented outside buildings to avoid the recirculation of return air. Existing sources of pollution such as leaded paint and asbestos insulation may either be removed or encapsulated. Increased ventilation and filtration are traditional approaches to ensuring good indoor air quality. Dehumidification helps in the reduction of microbial growth. Low humidity should be maintained inside a house to limit the growth of such bacteria.

Devices based on the principles of absorption and adsorption are finding applications in controlling indoor air pollutants and moisture. Solid and liquid **desiccants** have been found effective in removing moisture and a wide range of pollutants. Silica gel, activated alumina, and activated carbon are also used to adsorb gases and vapors. Spider plants have been found to absorb some volatile organic compounds (VOCs) from indoor air.

desiccant a chemical agent that absorbs moisture; some desiccants are capable of drying out plants or insects, causing death

The number of lawsuits filed in the area of indoor air pollution dramatically increased between 1970 and 2001. The U.S. Environmental Protection Agency's Building Assessment Survey Evaluation found that in the worst buildings of the first study group, approximately 30 to 40 percent of occupants experienced headaches, unusual fatigue or drowsiness, and dry, itching,

or otherwise irritated eyes at least once a week. In the best buildings of the same study group, 6 percent of occupants experienced unusual fatigue or drowsiness. Under these circumstances, the possibility of complaints filed in relationship to indoor air quality will not become remote in coming years. SEE ALSO Asbestos; Asthma; Household Pollutants; Lead; Mold Pollution; Pesticides; Radon; Tobacco Smoke.

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Ashok Kumar and Rishi Kumar

SICK BUILDING SYNDROME

Symptoms associated with building-related health problems are commonly referred to as sick building syndrome. The American Society of Heating, Refrigerating and Air-Conditioning Engineers describes a building in which more than 20 percent of its occupants report building-related illness as a sick building. Symptoms include, but are not limited to, irritation of eyes, nose, and throat; dryness of mucous membranes and skin; erythema; mental fatigue; headaches; airway infections; coughing; hoarseness; wheezing; nausea; dizziness; and unspecific hypersensitivity. It is difficult to identify specific causes of the problem. The complaints reported by the occupants of "sick buildings" are generally nonspecific in nature and, therefore, it is very hard to establish a causal relationship between symptoms and pollutants present in the building.

Industrial Ecology

Industrial ecology aims to reduce the environmental impact of industry by examining material and energy flows in products, processes, industrial sectors, and economies. Industrial ecology provides a long-term perspective, encouraging consideration of the overall development of both technologies and policies for sustainable resource utilization and environmental protection into the future. It emphasizes opportunities for new technologies and new processes, and those for economically beneficial efficiencies. Industrial ecology draws on and extends a variety of related approaches including systems analysis, **industrial metabolism**, materials flow analysis, life cycle analysis, pollution prevention, design for environment, product **stewardship**, energy technology assessment, and eco-industrial parks.

industrial metabolism flow of resources and energy in an industrial system

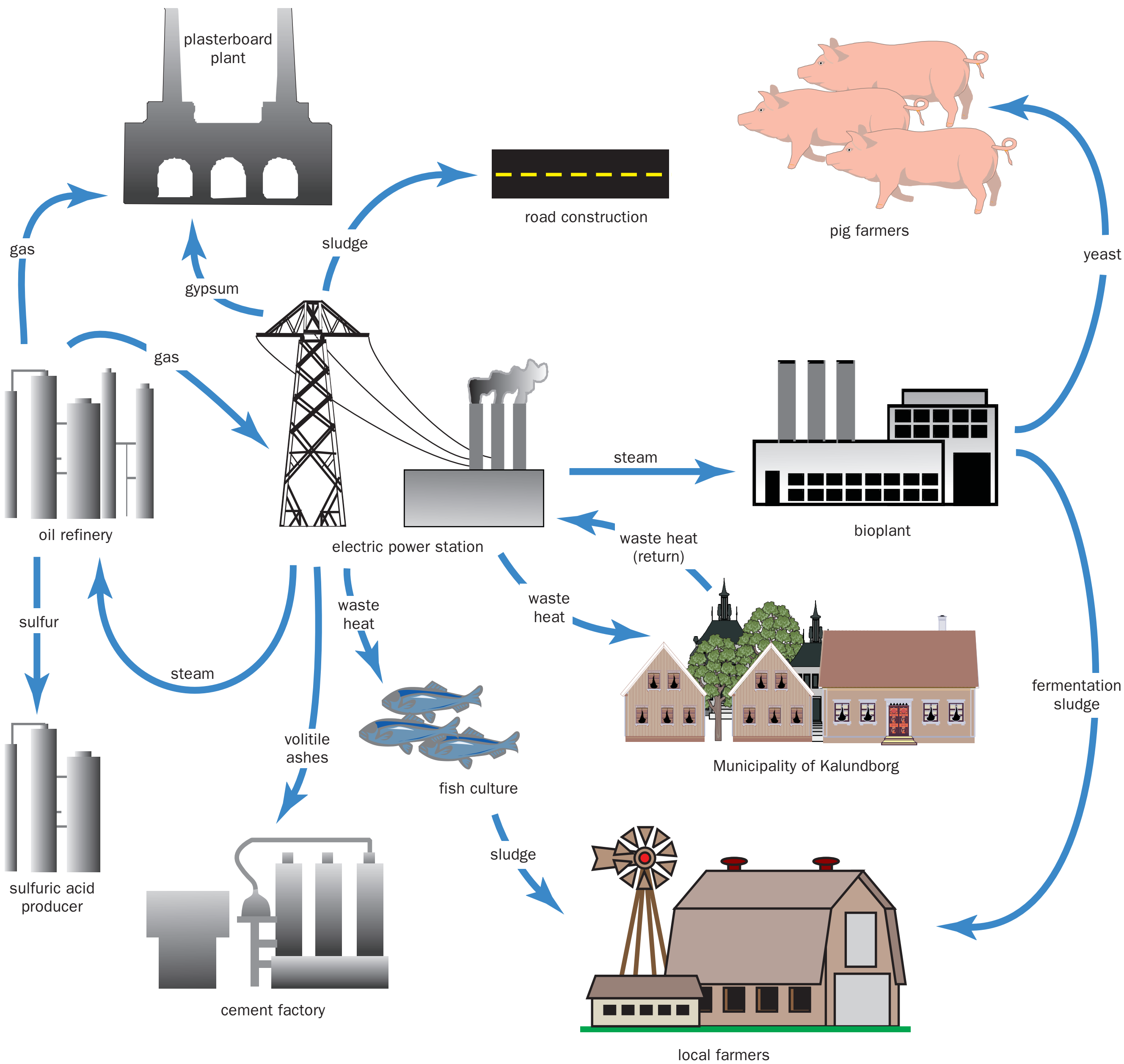
stewardship care for a living system

Greater material efficiency, the use of better materials, and the growth of the service economy can contribute to the "dematerialization" of the economy. Resources that are cheap, abundant, and environmentally benign may be used to replace those that are expensive, scarce, or environmentally harmful. Such a substitution can be seen in the many important changes in energy sources that have occurred over the past century. As the energy sources have shifted from wood and coal toward petroleum and natural gas, the average amount of carbon per unit energy produced has decreased significantly, resulting in the "decarbonization" of world energy use.

Another strategy for reducing environmental impact is the substitution of services for products, meaning that customers do not seek specific physical products, but rather the services provided by those products. For example, an integrated pest management service might provide crop protection rather than selling pesticides. The service thus saves money by using only as much pesticide as needed.

Another industrial ecology strategy is to use waste products as raw materials. These efforts often come into conflict with concerns about hazardous materials in the wastes, such as the concern that trace metals in ash from

INDUSTRIAL ECOSYSTEM AT KALUNDBORG, DENMARK



power plants recycled in fertilizer may contaminate soil. However, in some cases, such waste reuse can be successful. In the industrial district in Kalundborg, Denmark, several industries, including the town's power station, oil refinery, and plasterboard manufacturer, make use of waste streams and energy resources, and turn by-products into products.

There are many examples of technological innovations that have had significant environmental benefits. An important example is the replacement of chlorofluorocarbons (CFCs) with new compounds in order to protect the

stratospheric ozone layer. Other examples are the elimination of mercury in batteries, and the elimination of lead in gasoline, paint, and solder.

The challenge of industrial ecology is to understand how technological and social innovation can be harnessed to solve environmental problems and provide for the well-being of the entire world. SEE ALSO Chlorofluorocarbons (CFCs); Industry; Lead; Life Cycle Analysis; Recycling; Reuse.

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Valerie M. Thomas

Industrial Revolution *See Industry*

Industry

Throughout the world there are various types of pollution that interfere with the quality of life for all living creatures and with the natural functioning of the earth's ecological systems. Although some environmental pollution is a result of natural causes (such as methane emissions from cattle and toxic materials expelled from volcanoes), most pollution is caused by human activities.

Human Industrial Activities

In the United States, as is the case in most industrialized nations, the greatest source of pollution is the industrial community. According to the 2000 Toxics Release Inventory (TRI) of the U.S. Environmental Protection Agency (EPA), over 2.95 million metric tons (6.5 billion pounds) of toxic chemicals from about 2,000 industrial facilities are annually released into the environment, including nearly 45,360 metric tons (100 million pounds) of recognized carcinogens.

Early History

Human contamination of the earth's atmosphere has existed since humans first began to use fire for heating, cooking, and agriculture, approximately one-half million years ago. The mining and smelting of ores that accompanied the transition from the Stone Age to the Metal Age (roughly 5,000 years ago) resulted in wastes that spread potentially toxic elements such as lead, mercury, and nickel throughout the environment. Professor Clair Patterson, a geochemist at the California Institute of Technology, has stated that samples detected in Greenland ice cores at depths just over one kilometer (about 0.6 mile) show small but significant levels of lead present throughout the last eight thousand years. In 1994 scientists reporting in the journal *Science* (September 23, 1994) concurred with Patterson, saying, "Analysis of the Greenland ice core covering the period from 3,000 to 500 years ago—the Greek, Roman, Medieval and Renaissance times—shows that lead is present at

concentrations four times as great as natural values from about 2,500 to 1,700 years ago (500 B.C.E. to C.E. 300)."

Industrial Revolution

During the Industrial Revolution of the eighteenth and nineteenth centuries, pollution became a major problem with the introduction of the steam engine and a series of technological advances that led to the production of goods shifting from homes and small factories to large industrial factories. The invention of more productive processes to manufacture cotton textiles contributed greatly to the number of mills located in England, and later in the northeastern United States. The steam engine allowed capitalists to transfer their manufacturing plants away from naturally flowing waters (outside the city) to areas inside and around cities where more abundant labor was available. Pollution increased because of the more concentrated conditions within the industrializing cities and because of the use of artificially produced power (such as coal) that replaced the natural power of fast-running rivers.

Evidence of pollution during the early Industrial Revolution in England and the European continent is widespread. South Wales, located in southwestern England, was described by Adam Markham in *A Brief History of Pollution* (1994) as a "veritable witches cauldron of industrial pollution." Samples of hair from historical figures such as Isaac Newton and Napoleon Bonaparte show the presence of antimony and mercury at toxic levels not normally found in human hair.

Industry Groups

An industry is a collection of companies that operate in a related set of goods or services, which are eventually sold to purchasers. In any country, numerous industries work together to produce the necessary goods and services needed and desired for its people. By convention, industries are divided into three groups:

- *Primary industries* are involved in the collection, utilizing, and harvesting of resources directly produced by physical processes (e.g., mining and smelting).
- *Secondary industries* deal with manufacturing as they take raw materials, convert them in various ways, and produce tangible goods (e.g., automobile factories).
- *Tertiary industries* produce services for individuals and groups (e.g., advertising).

These three groups are distinctive regarding the amount of pollution produced in their operations. Some sectors (such as tourism) have a close relationship with the environment, whereas others have adopted a particularly proactive environmental response (such as the automobile industry with regard to recycling old cars) and still others continue to have a noticeable detrimental impact on the environment (such as the automobile industry with regard to exhaust emissions). Since the largest impact from pollution (and associated waste products) is produced within the secondary industries, this sector will be the topic of discussion in this article. Most economists commonly refer to the secondary industries (the manufacturing sector) as

A factory emitting large amounts of smoke into the air. (©Royalty-Free/Corbis. Reproduced by permission.)

"industry," whereas the primary industries are usually referred to as the agricultural and mining sector, and the tertiary industries as the service sector.

Public Perception

The public is becoming increasingly aware of the interactions and conflicts between industry and the environment. Events such as the 1989 oil spill from the tanker *Exxon Valdez* off Prince William Sound in Alaska—one of the most publicized and studied environmental tragedies—have highlighted the growing significance of maintaining a healthy environment while improving how corporations operate. Business responses to environmental influences fall within a wide spectrum of actions and inactions. On one side are businesses that attempt to decrease any negative impacts their activities have on the environment. For example, the 3M Corporation's Product Responsibility Program encourages its employees and business units to think from "cradle-to-the-grave" with respect to their products. On the other hand, some businesses have continued to pollute the environment while professing to be

environmentally conscious. For example, Royal Dutch/Shell has spent millions of dollars to create the impression that it is an environmentally responsible oil company. According to Jack Doyle, author of the book *Riding the Dragon: Royal Dutch Shell and the Fossil Fire* (2003), the company actively continues its efforts to suppress governmental articles that report on its environmental malfeasance.

Common Industrial Polluters

Many of the largest polluters come from the chemical, pesticide, oil refining, petrochemical, metal smelting, iron and steel, and food processing industries. All are major users of energy that produce large amounts of waste products and pollution. Other industries have less potential impact but are still considered highly problematic when it comes to pollution. These industries include the textile, leather tanning, paint, plastics, pharmaceutical, and paper and pulp industries. Industries that are often outside the traditional manufacturing sector—but nevertheless contribute to environmental degradation—include the construction industry, to name but one example.

Profit-principle Balancing Act

For industry, the bottom line is profits. In 1998 the chairman of The Royal Dutch/Shell Group of Companies, Mark Moody-Stuart, stated, "We believe that without principles, no company deserves profit. Without profits, no company can sustain principles." Alasdair Blair and David Hitchcock, authors of *Environment and Business* (2001), respond to this statement by noting the following about the remarks of the Shell chairman: He acknowledges the fact that profits without principles is immoral but, on the other hand, realizes that no company can afford to possess principles which go counter to profits.

There is an inevitable balancing act that must be played out by companies each and every day with respect to "principle" and "profit." No company can operate on purely proenvironmental decisions, nor can a company run solely on the basis of maximum profits. In the end, a company must choose a course of action that is somewhere in between the two extremes.

Evolution of Industrial Perspectives and Pollution

Pollution first became a persistent problem during the Industrial Revolution. The introduction of the factory system, the substitution of hand labor by machine labor (which led to dramatic rises in productivity), the application of power (mainly coal) to industrial processes, and the use of the railroad—all helped to accelerate the pollution problem. Early small-scale industries resulted in local concentrations of air and water pollution and land contamination. The area of London, England, is an obvious example of a locality steeped in considerable pollution. The manufacturing industries of the nineteenth century mostly involved the processing of natural materials such as cotton, leather, and other natural fibers along with the mining and fabrication of metal products.

As the scale of operations grew in the latter half of the nineteenth century, the amounts of pollution and land despoliation and the area over which it took place dramatically increased. The railroads paralleled this expansion. As the rails expanded westward from the New England states, pollution

followed in Chicago, Illinois; St. Louis, Missouri; and Detroit, Michigan; and later in Houston, Texas; Denver, Colorado; and Los Angeles, California (to name a few of the states affected). The twentieth century saw the rapid development of industries based on the chemical manufacturing of such items as dyes, plastics, and pharmaceuticals. Oil replaced coal as industry's primary power and energy source. The same era witnessed drastic changes in the structure, nature, and organization of factories as they quickly converted to mass production techniques to keep up with demand. By the close of the twentieth century, companies had advanced from plant-wide organizations to worldwide operations. Throughout the twentieth century, the advancement of technology allowed large corporations to dominate the industrial landscape, and to have a most drastic effect on the environment. To counter some negative environmental impact, the final decade of the twentieth century saw a positive shift in emphasis from "end-of-pipe" controls on releases into the environment to the elimination of potential pollution at its source ("beginning of pipe"). Rather than trying to "fix" a problem that had already occurred, industry began to "eliminate" the problem before it occurred.

Environmentalism. During the Industrial Revolution, companies were virtually consumed with production and profits. There was little time for or concern with the effects of pollution. Companies were by and large concerned with the means of production rather than the effect of production on the environment. Once the wealth generated by the mass production of goods slowly drifted down to common workers, more questions were raised about the air and water pollution being generated by factories. Environmental changes did occur gradually in the next hundred years. But it was the 1960s that saw the greatest increase in environmental concerns raised by the public. Business was perceived as the enemy, and the mass environmental movement brought on by a rejection of social and political traditions of the past forced many changes to the indifference previously displayed by business toward the environment.

The pressures on companies to reduce pollution have varied over time with societal expectations and attitudes. For example, air pollution was a concern in the 1850s when English companies emitted noxious pollutants from their chimneys. In England beginning in 1863, legislation was passed, the so-called Alkali Acts, which eventually improved atmospheric conditions. However, companies continued to emit smoke as a result of coal burning. This problem continued to worsen, and smog became an increasing concern in the mid-twentieth-century skies over London. Public concern was generated after health problems were linked to such soot emissions, and passage of the British Clean Air Act of the 1950s was the result. Today, power stations in England are under pressure to fit scrubbers to their emission systems to reduce atmospheric sulfur emissions.

Environmental Business Costs

Environmental advancements have been made over the past 150 years regarding industrial behavior. In the past, companies had been able to regard the air, land, and water as free goods. Often, companies saw the pollution they generated as something they could externalize. That is, since air, land, and water pollution usually affects areas that businesses do not own, then it was not their responsibility to address and consequently there was no need to

increase costs in order to limit their wastes. Industrial polluters then passed on the environmental costs of their operations, instead of incorporating them into their own cost structure. Today, the attitude is completely different: The originator is responsible, on both a legal and moral basis, for the spread of pollutants into the air, land, and water, and must shoulder the cost of any required cleanup.

Environmental costs are a legitimate and justifiable part of doing business, but as with any cost, it is desirable to minimize these costs as much as possible. Environmental costs may be brought into a company as an internal cost for these reasons:

- *Compliance with regulations or anticipation of future regulations:* Directed by national or state requirements, all companies must obey laws enacted by governments. For example, coal-burning factories install desulfurization equipment when mandated by the government.
- *Image building or eco-efficiency:* Even though no laws apply, companies might voluntarily use environmentally safe processes when seen as not living up to social norms. For example, Shell Oil towed its faulty Brent Spar oil platform to shore after public protest against its planned disposal on the seafloor.
- *Sustainable development initiatives:* Companies might add environmental policies when potential savings could be realized in the long term. This concept is basic to the guidelines established by the United Nations Conference on Environment and Development, which sees sustainable development as an essential part of its pollution-prevention philosophy.
- *Voluntary cleanup programs:* Companies often volunteer to clean up pollution as a result of pressures from politicians, the public, and the government. Many companies would rather pay the extra cost to clean up, rather than fight the problem in court and risk bad publicity in the media.
- *Initiatives to attain international certification:* Often, in order to expand to overseas markets, companies must strengthen their regulatory standards to achieve certification throughout all trading countries. For instance, a company that wishes to trade internationally must meet the rules enacted by the General Agreement on Tariffs and Trade (GATT), which is the principal international group whose rules govern the majority of international trade.

Unchanged Industry Behavior

Sometimes, polluting companies have not succumbed to social, political, and governmental pressures. Several companies have denied responsibility for pollution even when faced with strong evidence to the contrary. Other companies, after admitting responsibility, promise strong action, but deliver nothing. Still other companies have performed admirably when it comes to being environmentally friendly. However, industry, for the most part, is only responding to the general demand for a higher material standard of living—that is, giving consumers what they want. If products continue to take priority over pollution control, then the fault must be one shared between the consumer and the producer.

Throughout modern history, individuals and small groups have agitated against various types of pollution. The advent of U.S. and English conservation societies, beginning with the Industrial Revolution, brought to the forefront new environmental issues. There are presently thousands of nongovernmental organizations (NGOs) that exist in virtually all the world's free-speech countries, including international organizations such as Greenpeace, Friends of the Earth, and the Sierra Club, to small local organizations that fight to control the pollution of their waters and lands.

However big or small, environmental groups help to publicize industries that pollute. In every case, industry has important decisions to make regarding how it conducts business. It may pollute the environment, but the very pollution that it expels may one day bring an end to its profits. The balancing act that industry now faces with regard to pollution and profits is difficult, at best.

The industrialization of the world has had a profound effect on its people and environment. Industry has not always performed admirably with respect to its responsibility for the pollution it expels into the ecosystem. Nonetheless, with current governmental regulations, the efforts of individuals and environmental groups, and the realization by leaders of industry, themselves, that a healthy environment is good for business and profits, the industrial community is more effectively balancing profits with its environmental responsibility to the general satisfaction of most people. SEE ALSO Laws and Regulations, International; Laws and Regulations, United States; Lifestyle; Mass Media.

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William Arthur Atkins & Philip Koth

Infectious Waste

Infectious waste is that portion of medical waste that is contaminated with pathogens that may be able to transmit an infectious disease; it is also referred

to as regulated medical waste. Infectious waste represents a small percentage (usually between 5 and 15 percent) of a health care facility's total waste stream. In the United States each state defines and sets standards for management, treatment and disposal of infectious waste. Most definitions concur that the following wastes should be classified as infectious waste: sharps (i.e., needles, scalpels, etc.), laboratory cultures and stocks, blood and blood products, pathological wastes, and wastes generated from patients in isolation because they are known to have an infectious disease. Infectious wastes can be treated (disinfected or sterilized) by thermal or chemical means prior to disposal.

For an infectious disease to be transmitted from contact with waste, there must be a sufficient concentration of pathogens (e.g., bacteria, viruses), a portal of entry, a mode of transmission, and sufficient virulence of the pathogen to affect a susceptible host. As a result the wastes of greatest concern in transmitting diseases are sharps (needles, scalpels, etc.). SEE ALSO MEDICAL WASTE.

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Hollie Shaner and Glenn McRae

Information, Access to

The generation and distribution of public information play a central role in the evolution of a strong democracy. Quality information is essential for effective governmental programs. The U.S. Constitution mandates a population census every ten years to apportion congressional representation. Land and water maps were necessary for defense, navigation, and planning the development of the frontier. By the late 1800s the Departments of Interior, Agriculture, and Commerce were charged with acquiring, analyzing, and disseminating environmental data for agency use, promoting business, and educating citizens. With the discovery of the germ theory of disease in the late nineteenth century, states began mandatory testing of public water supplies.

In the twentieth century, government rapidly expanded as the population grew and the economy was transformed from agricultural to industrial. Rapid increases in energy and chemical use were soon followed by widespread problems of pollution. Public concern led to increased regulation. From the 1970s onward major environmental laws were enacted to protect human health and the ecosystem. Each regulation contains specific data requirements that classify substances, and document location, utilization, and dispersal. The result is that numerous agencies now collect, process, and disseminate environmental information.

EVOLUTION OF POLLUTION INFORMATION ACCESS

Date	Policy	Content	Access Process
1946	APA—"Need to Know"	Agency Record Series	In Person Copying
1966	FOIA—"Right to Know"	Agency Record Series	Written Request
1986	EPCRA—Community Response	Local Facility On-Site Chemical Storage	Written Local Request
1986	TRI—Toxic Release Inventory	Annual Chemical Releases to receiving media: air, water, surface, subsurface, offsite	Digital disk-facility, zip, municipality, county, state
1996	E-FOIA—Web Reading Room	Frequently Requested Data	Internet Search
1999	EPA Office of Environmental Information	Centralized "Envirofacts" Data Warehouse	Internet Interactive GIS
2001	**Response to 9/11/01 Terrorist Attack**	**Maps and Data regarding dams, Power Plants, Water Supplies, and other potential Terrorist targets**	**Removed from Public Internet Access**

Public data acquisition is shaped by four factors: legitimacy, resources, access, and will. Agencies can only collect data that meet a specific program objective, such as a metropolitan smog reduction program requiring automobile exhaust testing. Compiling data requires staff, equipment, and travel. Most monitoring programs rely on statistical sampling, and some have insufficient budgets to meet desired quality standards. Pollution often involves activities by private enterprise such as manufacturing. Governments must follow strict procedures before entering these facilities to collect data. Periodically, elected and appointed officials decide not to mandate data collection activities that are unpopular with constituent groups including businesses, farmers, or homeowners.

Public Access to Information

Elected officials and agency administrators are accountable to the public. As government grew, program complexity hindered information access. In 1946 the Administrative Procedures Act (APA) required agencies to make public for review and copying its organization description, decision processes, data collection procedures, and lists of data sets (record series). In practice, however, data access was often denied. Requestors were required to document their intended uses ("need to know"). Rachel Carson encountered this roadblock while researching how DDT was deforming and killing wildlife for her book, *Silent Spring*. In 1966 Congress amended APA with the Freedom of Information Act (FOIA). It establishes a broad public "right to know," requiring agencies to process a data request unless it conflicts with one of nine categories of specific exclusion such as national defense. FOIA entails a specific written request and often takes months to process. Most states also now have similar APA and FOIA laws for state and local agencies.

When FOIA was enacted, computers were not widely available. The digital information revolution has dramatically changed all aspects of data acquisition, analysis, and dissemination. FOIA was amended in 1996 as the Electronic FOIA (E-FOIA) to expand the definition of "records" to include digital files, and requires agencies to create Internet-based *electronic reading rooms*, where the public can locate, access, and download frequently requested data without filing a formal request.

Kinds and Sources of Information

In response to the factors that shape the government's ability to collect data, a variety of alternative approaches have been developed to facilitate the creation of pollution-related information. *First party* data are acquired directly by a government agency. This approach is well suited to long-term programs designed to assess environmental change. For example, New York state operates a network of air pollution monitoring stations. Much pollution emissions data, however, are *second party.* That is, regulations require businesses to self-monitor their discharges and report them to the appropriate governmental unit in a standard format to become part of the public record. Most land disposal, air, water, and hazardous waste permits are of this type. Under the Emergency Planning and Community Right-to-Know Act (EPCRA), businesses must report chemicals stored on-site to local emergency response committees, and annually report pollution releases to the states (the Toxic Release Inventory, TRI). Some hazard data are *third party*, with the government requiring the exchange of information between two private parties. For example, Florida requires home sellers to test for radon, and report the results to prospective buyers. Unless specified, third party information is typically not a public record.

A fourth approach, increasing in importance, is field monitoring programs conducted by not-for-profit groups and academic institutions under the technical guidance of a government agency. The National Environmental Policy Act of 1970 (NEPA) states that citizens have a major responsibility for creating a healthy environment. Challenges such as the nonpoint pollution of water supplies need locally based continuing data collection. Citizens are then prepared to take proactive roles in management decisions. These programs often combine chemical analyses with the recording of bio-health indicators such as stream organisms. Examples include the Pennsylvania Alliance for Aquatic Resource Monitoring and the Rivers of Colorado Water Watch.

Formats of Information

Most federal and state environmental data are now available in a digital format. Typically, the data have two components: spatial (map) location, and descriptive data table attributes such as date, chemical type, and amount or concentration. Initially, each pollution program such as air emissions or Superfund, was managed with an independent database. This presented major difficulties in combining information across programs. The establishment of a mandated Toxic Release Inventory (TRI) was a major innovation, integrating multimedia pollution data. In recent years the Environmental Protection Agency (EPA) has integrated databases in its "Envirofacts" data warehouse. With the advent of the Internet, the user interface for selecting information has become highly flexible and interactive. EPA's TRI data can be accessed by geography (zip code, county, state, or nation), chemical, industry sector, or year. Users can also specify the type of report desired, such as a trend analysis. The agency's EnviroMapper program uses an interactive geographic information system (GIS) that allows point-and-click zoom access for location selection. The user can then select which data to display.

In addition to data dissemination, public agencies and some nonprofit organizations are now using the Internet to communicate summary analyses

of environmental quality. EPA's GIS-based "Surf Your Watershed" creates a multifactor index of water indicators (IWI) "scorecard" total for current quality and future vulnerability. Graphs of factors can also be produced. Many innovative approaches to disseminating pollution information are being developed around the world. Canada's National Water Resource Institute has developed the RIASON system for local and international use that integrates multiple databases, GIS, and analysis capabilities. It has been used to assess acid rain in North America, and protect rural water supplies in African Lake Malawi (Lake Nyasa). In England, the U.K. National Air Quality Information Archive Web site provides interactive access to historical and current monitoring data, including health alert bulletins.

Use of Information

Environmental management is a shared responsibility of the public, business, and government. The public continuously makes consumer choices such as where to reside and what herbicides to use based on available information. Citizens also participate as partners in local pollution monitoring and environmental restoration projects. Businesses use pollution data to improve competitiveness through better manufacturing practices. Governments use the data for advancing the scientific understanding of complex systems, for establishing and enforcing standards, and for education.

Open access to pollution information plays a critical role in shaping public policy. Locally, information provides the foundation for land-use plans, emergency response, Brownfield cleanup, the protection of community water supplies, and the issuance of health alerts. At the state and national levels, pollution monitoring is essential for measuring the effectiveness of existing programs and establishing the need for new interventions. Pollution knows no political boundaries. Global warming, ocean dumping, and safe drinking water challenge the sustainability of the planet. The United Nations Environment Program is leading the collaborative effort to establish standardized, long-term public and private global monitoring and data sharing. SEE ALSO GIS (GEOGRAPHIC INFORMATION SYSTEM); RIGHT TO KNOW.

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John P. Felleman

Injection Well

Injection wells use high-pressure pumps to inject liquid wastes into underground geologic formations (e.g., sandstone or **sedimentary** rocks with high **porosity**). Many geologists believe that wastes may be isolated from drinking water aquifers when injected between **impermeable** rock strata. However, injection wells are still controversial and many scientists are concerned that leaks from these wells may contaminate groundwater. As of 1994, twenty-two out of 172 deep injection wells contaminated water supplies.

sedimentary related to or formed by deposition of many small particles to form a solid layer

porosity degree to which soil, gravel, sediment, or rock is permeated with pores or cavities through which water or air can move

impermeable not easily penetrated; the property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water

brine salty water

There are five classes for injection wells based on the type of fluid injected and the location of the wells. Class I wells inject hazardous or nonhazardous fluids into isolated rock formations, approximately four thousand feet below the surface, and are strictly regulated under the Resource, Conservation and Recovery Act (RCRA). Their use must demonstrate that underground drinking water sources won't be contaminated. Class II wells are commonly used for the disposal of **brine** created during oil and gas production. Class III wells inject superheated steam or fluids and then extract them from the geologic formation to remove valuable minerals. Class IV wells were used for injection of hazardous or radioactive wastes, but are currently banned in the United States due to possible contamination of shallow drinking water sources. Class V wells (those not included in Classes I–IV) inject waste into the ground and allow it to drain by gravity into shallow **aquifers**, providing little or no protection against groundwater contamination. Examples include drainage wells, **septic tanks**, and **cesspools**.

aquifer an underground geological formation, or group of formations, containing water; are sources of groundwater for wells and springs

septic tank an underground holding tank for wastes from homes not connected to a sewer line

cesspool holding compound for sewage in which bacterial action breaks down fecal material

The Environmental Protection Agency (EPA) estimates that over 400,000 injection wells, receiving nine billion gallons of hazardous waste annually, exist in the United States. As of 2002, there were 473 Class I injection wells of which 123 were used to dispose of hazardous waste. Lesser-developed countries (e.g., Mexico) also use injection wells for waste disposal and often have fewer regulations than the United States.

In the United States, injection well **casings** must provide **double containment** to compensate for any structural failure. Wells are tested every five years for **integrity** (more frequently for hazardous waste) and are monitored continuously for possible contamination. Because of the threat of contaminating underground drinking water sources, the EPA establishes minimum requirements for the location, construction, operation, maintenance, monitoring, testing, and closure of injection wells. All such wells require authorization or specific permits.

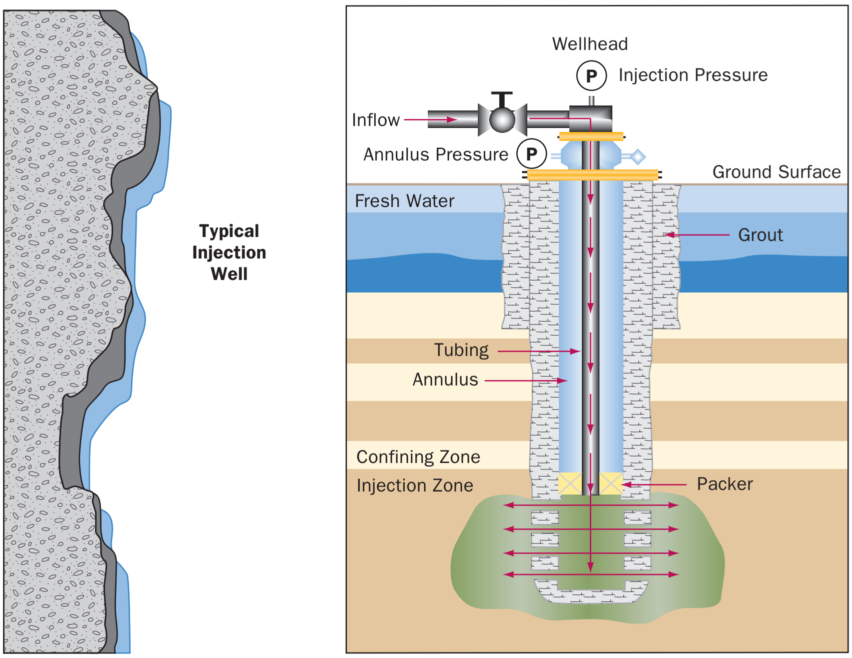
casing the exterior lining of the well

double containment use of two independent protection systems around a potential pollutant

integrity wholeness and stability

Although some believe that properly constructed and operated injection wells are an environmentally sound disposal method for hazardous waste, fractures in rock layers often allow drinking water sources to become contaminated, and the ultimate fate of injected contaminants is unknown. SEE ALSO HAZARDOUS WASTE; RESOURCE CONSERVATION AND RECOVERY ACT (RCRA); WATER POLLUTION.

DIAGRAM OF INJECTION WELL



SOURCE: Adapted from the National Energy Technology Laboratory.

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Margrit von Braun and Deena Lilya

Integrated Pest Management

Integrated pest management (IPM) refers to strategies used to minimize the application of chemical pesticides and to combat plant pests, such as insects and other **arthropods**, pathogens, **nematodes**, weeds, and certain vertebrates, without incurring economic plant damage. All plant pests (as well as other life-forms) have natural enemies, and the use of such biological control agents is commonly thought to form the basis of IPM. Biological control can be practiced through the introduction, encouragement, and/or release in high numbers of appropriate natural enemies of plant pests. However, in many cases, particularly those involving pests other than insects, biological control may be insufficient to provide economic management of pests on crops or other plants valued by humans. Therefore, IPM utilizes an arsenal of additional strategies to accomplish its goals. These tactics may include periodic sampling of plants to determine if and when pesticides must be used to avoid economic damage, and when the target pests are most

arthropod insects, spiders, and other organisms with jointed appendages and hard outer coverings

nematode worm-like organisms common in soil

susceptible to the least amount of pesticidal treatment. Elements of cultural or physical management, such as crop rotation, destruction of infested plant material which may serve as a source of subsequent pest problems (sanitation), or use of high temperatures or moisture (flooding) to destroy pests. Most of these strategies can be used by home gardeners, as well as by farmers, and are site or situation specific to a particular plant environment.

There are many variants of IPM philosophy. These differences form a continuum from simply using knowledge of pest biology to apply pesticides with timing that is optimal for managing pests, while minimizing applications of pesticides, to the total exclusion of "hard" pesticides in favor of "soft" or naturally derived materials that are less disruptive to nontarget organisms and the environment ("bio-intensive" or "bio-based" IPM).

This type of bio-intensive IPM is not much different from some forms of organic or ecological plant culture. Like IPM, organic growing philosophy has many variants, and most of these allow the use of certain naturally derived, as opposed to synthetic, pesticides. However, many of these types of natural materials can also become pollutants, if used unwisely or in large quantities. SEE ALSO Agriculture; Pesticides; Sustainable Development.

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James J. Stapleton

Ishimure, Michiko

The methyl-mercury poisoning in Minamata Bay first became apparent in 1953, with sick children and "dancing cats," cats so frenzied they would "dance" and die. Initially it was thought that this was a contagious disease, and the victims were spurned by other villagers. It became obvious in the late 1950s that the release of methyl mercury from the Chisso chemical plant in Minamata Bay had caused high levels of mercury in fish, which resulted in the health problems of the local community, especially fishermen. Michiko Ishimure was a shy housewife from Minamata who was concerned about the plight of the villagers, who became ill from ingesting high levels of mercury.

Ishimure, who talked with many of the sick and dying, wrote *Cruel Tales of Japan: Modern Period,* her first account of the toxic effect of mercury poisoning in 1960. Her second, definitive work on the "Minamata disease" (*Paradise in the Sea of Sorrow*) appeared in 1969. This book won several awards, all of which Ishimure refused as long as the plight of the victims was not recognized. She organized a photo exhibition to bring the horrors of the disease to the world, but the powers of industry and government refused to take notice

for a long time. It was not until 1968 that the Japanese government placed the responsibility of the pollution with the chemical plant. Even then it took a long time for the victims to receive monetary compensation.

Michiko Ishimure has been compared to Lois Gibbs, another woman activist, who rose from the status of common housewife to a leader-activist in the Love Canal pollution case. Ishimure is generally credited with keeping up the pressure on both industry and the Japanese government by publishing books and articles about a "disease" that most Japanese did not want to hear about. That she was a mother turned poet, writer, and activist in a country where women in general were subservient to men makes her contribution even more remarkable. Although she is no longer a leader in the movement for the rights of Minamata disease victims, her book has gone through thirty printings, and she still writes articles and gives lectures on the topic. SEE ALSO MERCURY.

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Johan C. Varekamp

ISO 14001

One of the more successful outcomes of the Earth Summit held in Rio de Janeiro in 1992 was the initiation of a process that would lead to the creation of an international environmental management standard. At the conclusion of the summit, the organizing committee asked the International Organization for Standardization (IOS) to evaluate the feasibility of developing such a standard in order to create some consistency in regulation among and discourage pollution by foreign interests in the many countries that were each developing their own set of environmental rules and laws. The IOS agreed and in August 1996 published the ISO 14001 Environmental Management Standard, the first in a series of standards to help organizations systematically improve their environmental performance. ISO 14001 is not, however, a performance standard. Rather, it specifically lists the elements and processes that need to be in place and fully operational within an organization to ensure that it is capable of achieving the level of environmental performance deemed appropriate to the nature, scale, and environmental impacts of its activities, products, and services.

ISO 14001 follows the "plan, do, check, act" strategy inherent in modern quality-management systems. The three basic tenets of the standard involve these commitments: compliance with all applicable environmental laws and regulations; prevention of pollution; and continual improvement. Conformance with the ISO 14001 standard is a voluntary measure that has been

widely adopted in the European Union (EU) and to a lesser degree in the United States as a prerequisite to doing business. Thus, although voluntary, it has become an economic necessity, and unlike government initiatives, it is driven by concerns of commerce rather than regulatory mandates. SEE ALSO Economics; Industry; Laws and Regulations, International.

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John Morelli

Glossary

24-hour standard: in regulations: the allowable average concentration over 24 hours

absorption spectrum: "fingerprint" of a compound generated when it absorbs characteristic light frequencies

absorption: the uptake of water, other fluids, or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in soil)

acetylcholine: a chemical that transmits nerve signals to muscles and other nerves

acute: in medicine, short-term or happening quickly

adherence: substances: sticking to; regulation: abiding by

adjudicative: involving the court system

adsorption: removal of a pollutant from air or water by collecting the pollutant on the surface of a solid material; e.g., an advanced method of treating waste in which activated carbon removes organic matter from wastewater

advise and consent: the formal responsibility of a government body to provide counsel and approval for the actions of another body, especially the Senate to the president

aerate: process of injecting air into water

aerobic: life or processes that require, or are not destroyed by, the presence of oxygen

affinity: physical attraction

afforestation: conversion of open land to forest

air scrubbers: pollution-control devices that remove pollutants from waste gases before release to the atmosphere

air stripping: a treatment system that removes volatile organic compounds (VOCs) from contaminated groundwater or surface water by forcing an airstream through the water and causing the compounds to evaporate

allergen: a substance that causes an allergic reaction in individuals sensitive to it

alloy: mixture of two or more metals

alluvial: relating to sediment deposited by flowing water

alpha radiation: fast-moving particle composed of two protons and two neutrons (a helium nucleus), emitted by radioactive decay

ambient: surrounding or unconfined; air: usually but not always referring to outdoor air

anaerobic: a life or process that occurs in, or is not destroyed by, the absence of oxygen

antagonistic: working against

anthropogenic: human-made; related to or produced by the influence of humans on nature

antimicrobial: an agent that kills microbes

aquaculture: practice of growing marine plants and raising marine animals for food

aquifer: an underground geological formation, or group of formations, containing water; are sources of groundwater for wells and springs

archetype: original or ideal example or model

arithmetic: increase by addition, e.g., 2, 4, 6, 8 . . . as opposed to geometric, in which increase is by multiplication, e.g., 2, 4, 8, 16 . . .

arthropod: insects, spiders, and other organisms with jointed appendages and hard outer coverings

asbestosis: a disease associated with inhalation of asbestos fibers; the disease makes breathing progressively more difficult and can be fatal

asymmetrical warfare: conflict between two forces of greatly different sizes; e.g., terrorists versus superpower

autoimmune: reaction of the body's immune system to the body's own tissues

baghouse: large fabric bag, usually made of glass fibers, used to eliminate intermediate and large particles

ballast: material in a ship used for weight and balance

bed load transport: movement of sediments that remain at the bottom of a moving water body

beta radiation: high-energy electron, emitted by radioactive decay

bilge: deepest part of a ship's hold

bioaccumulation: buildup of a chemical within a food chain when a predator consumes prey containing that chemical

bioaccumulative: relating to substances that increase in concentration in living organisms as they take in contaminated air, water, or food because the substances are very slowly metabolized or excreted

bioaerosol: very fine airborne particles produced by living organisms

bioassay: a test to determine the relative strength of a substance by comparing its effect on a test organism with that of a standard preparation

bioavailability: degree of ability to be absorbed and ready to interact in organism metabolism

bioconcentrate: chemical buildup in an organism, i.e., fish tissue, to levels higher than in the surrounding environment

biodegradation: decomposition due to the action of bacteria and other organisms

biodegrade: to decompose under natural conditions

biodiversity: refers to the variety and variability among living organisms and the ecological complexes in which they occur; for biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity; thus, the term encompasses different ecosystems, species, and genes

biogeochemical interaction: interactions between living and nonliving components of the biosphere

biological capital: oceans, forests, and other ecosystems that provide resources or other values

biological effects: effects on living organisms

bioluminescence: release of light by an organism, usually a bacterium

biomass: all of the living material in a given area; often refers to vegetation

biomonitoring: the use of living organisms to test the suitability of effluents for discharge into receiving waters and to test the quality of such waters downstream from the discharge; analysis of blood, urine, tissues, etc. to measure chemical exposure in humans

bioremediation: use of living organisms to clean up oil spills or remove other pollutants from soil, water, or wastewater; use of organisms such as non-harmful insects to remove agricultural pests or counteract diseases of trees, plants, and garden soil

biosolid: solid or semisolid waste remaining from the treatment of sewage

bituminous: soft coal, versus the harder anthracite coal

boom: a floating device used to contain oil on a body of water; or, a piece of equipment used to apply pesticides from a tractor or truck

boreal: northern, subarctic

botanical: derived from or relating to plants

breakdown product: part of a whole resulting from a chemical transformation

breakdown: degradation into component parts

brine: salty water

British thermal unit (BTU): unit of heat energy equal to the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit at sea level

bush-fallow: practice of alternating between cultivating a piece of land and leaving it unplanted

cabinet: in government: collective name for the heads of federal departments that report directly to the president

carbamate: class of chemicals widely used as pesticides

carcinogen: any substance that can cause or aggravate cancer

carcinogenic: causing or aggravating cancer

cascade: waterfall; a system that serves to increase the surface area of the water to speed cooling

casing: the exterior lining of the well

catalyst: a substance that changes the speed or yield of a chemical reaction without being consumed or chemically changed by the chemical reaction

catalytic: of a substance that promotes reaction without being consumed

cesspool: holding compound for sewage in which bacterial action breaks down fecal material

chelating agents: chemicals that trap metal ions (*chele* = claw)

chemically active: able to react with other chemicals

chloramination: use of chlorine and ammonia to disinfect water

chromatography: means of resolving a chemical mixture into its components by passing it through a system that retards each component to a varying degree

chronic: in medicine, long-term or happening over time

claim: legal statement of intent

clarifier: a tank in which solids settle to the bottom and are subsequently removed as sludge

codify: put into law

coke: carbon fuel, typically derived from bituminous coal, used in blast furnaces for the conversion of iron ore into iron

combustion: burning, or rapid oxidation, accompanied by release of energy in the form of heat and light

complex emergency: a humanitarian crisis in which there is a breakdown of political authority

compliance: in law: meeting the terms of a law or regulation

computer model: a program that simulates a real event or situation

concordance: state of agreement

condenser: apparatus used to condense vapors

congener: a member of a class of chemicals having a of similar structure

consensus-building: negotiation to create agreement

consent order: a legal agreement requiring specific actions to remedy a violation of law

conservation easement: legal agreement restricting a landowner's development rights to preserve long-term conservation and environmental values

conservationist: a person who works to conserve natural resources

containment: prevention of movement of material beyond the immediate area

contaminant: any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil

control rod: a rod containing substance that absorbs neutrons inserted into a nuclear reactor to control the rate of the reaction

conversion: chemical modification to another form

counterculture: a culture with social ideas that stand in opposition to the mainstream culture

criteria pollutant: a pollutant for which acceptable levels can be defined and for which an air quality standard has been set

crop rotation: alternation of crop species on a field to maintain soil health

cultivar: a plant variety that exists only under cultivation

DDT: the first chlorinated hydrocarbon insecticide chemical name: Dichloro-Diphenyl-Trichloroethane); it has a half-life of fifteen years and can collect in fatty tissues of certain animals; for virtually all but emergency uses, DDT was banned in the U.S. in 1972

defoliant: an herbicide that removes leaves from trees and growing plants

defoliation: loss of vegetation

deicer: chemical used to melt ice

denitrification: the biological reduction of nitrate or nitrite to nitrogen gas, typically by bacteria in soil

deposit: concentration of a substance, i.e., mineral ore

desertification: transition of arable land to desert

desiccant: a chemical agent that absorbs moisture; some desiccants are capable of drying out plants or insects, causing death

despoliation: deprivation of possessions by force

deuterium: a hydrogen atom with an extra neutron, making it unstable and radioactive

diatomaceous earth: a chalk-like material (fossilized diatoms) used to filter out solid waste in wastewater treatment plants; also used as an active ingredient in some powdered pesticides

diffuser: something that spreads out or dissipates another substance over a wide area

dinoflagellate: single-celled aquatic organism

dioxin: any of a family of compounds known chemically as dibenzo-p-dioxins; concern about them arises from their potential toxicity as contaminants in commercial products; tests on laboratory animals indicate that it is one of the more toxic anthropogenic (man-made) compounds

disaster cycle: phases in the public response to a disaster: preparedness, disaster, response, recovery, and mitigation of effects

dissolution into the oceans: dispersion in ocean water

dissolved oxygen: the oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors; DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life; secondary and advanced waste treatment are generally designed to ensure adequate DO in waste-receiving waters

distillation: the act of purifying liquids through boiling, so that the steam or gaseous vapors condense to a pure liquid; pollutants and contaminants may remain in a concentrated residue

double containment: use of two independent protection systems around a potential pollutant

drier: a compound that increases the drying rate

drilling waste: material (soil, ground rock, etc.) removed during drilling

drinking water: water used or with the potential to be used for human consumption

ecosystem: the interacting system of a biological community and its nonliving environmental surroundings

effluent: discharge, typically wastewater—treated or untreated—that flows out of a treatment plant, sewer, or industrial outfall; generally refers to wastes discharged into surface waters

efflux pump inhibitors: a drug that prevents a cell from expelling another drug; used with antibiotics to increase their effectiveness

electoral consensus: the will of the voters

electrode: conductor used to establish electrical contact with a substance by delivering electric current to it or receiving electric current from it

electromagnetic spectrum: the range of wavelengths of light energy, including visible light, infrared, ultraviolet, and radio waves

emissions: substances, often polluting, discharged into the atmosphere

endocrine: the system of glands, hormones, and receptors that help control animal function

endocrine disruption: disruption of hormone control systems in the body

environmental stewardship: human commitment to care for the environment

epidemic: rapid spread of disease throught a population, or a disease that spreads in this manner

epidemiological: epidemiology: study of the incidence and spread of disease in a population

epidemiology: study of the incidence and spread of disease in a population

epilepsy: seizure disorder

estrogenic: related to estrogens, hormones that control female sexual development

estuary: region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh- and saltwater (i.e., bays, mouths of rivers, salt marshes, and lagoons). These ecosystems shelter and feed marine life, birds, and wildlife

eutrophication: in nature, the slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears; in pollution, excess algal growth or blooms due to introduction of a nutrient overload of nutrients, i.e., from un- or poorly treated sewage

evaporative: relating to transition from liquid to gas

excavate: dig out

excess death: deaths over the expected number

exothermic: releasing heat

fatalistic: of a person who believes that nothing one does can improve a situation

fecal matter: animal or human excrement

fetus: unborn young of vertabrate animals; human: developing child in the womb from eighth week to birth

filtration: process for removing particulate matter from water by means of porous media such as sand or synthetic filter

flammable: any material that ignites easily and will burn rapidly

flux: 1. a flowing or flow; 2. a substance used to help metals fuse together

French drain: buried plastic tubing with numerous holes, to collect or disperse water

friable: capable of being crumbled, pulverized, or reduced to powder by hand pressure

fungicide: pesticide used to control, deter, or destroy fungi

gamma radiation: very high-energy light with a wavelength shorter than x rays

gelling agent: chemical used to thicken a substance, i.e., oil, to prevent it from spreading out

genetic diversity: the broad pool of genes that insures variety within a species

Geneva Conventions: humanitarian rules governing treatment of soldiers and civilians during war

geometric: by multiplication, e.g., 2, 4, 8, 16 . . ., as opposed to arithmetic, in which increase is by addition, e.g., 2, 4, 6, 8 . . .

global warming: an increase in the near-surface temperature of the Earth; the term is most often used to refer to the warming believed to be occuring as a result of increased emissions of greenhouse gases

grassroots: individual people and small groups, in contrast to government

green choice: a product that is not harmful for the environment

greenhouse gas: a gas, such as carbon dioxide or methane, which contributes to potential climate change

groundwater: the supply of freshwater found beneath the Earth's surface includes; aquifers, which supply wells and springs

guano: solid or semisolid waste from birds and bats, rich in nutrients

Hague Conventions: international agreements governing legal disputes between private parties

half-life: the time required for a pollutant to lose one-half of its original concentration; for example, the biochemical half-life of DDT in the environment is fifteen years

halogenated organic compounds: organic (carbon-containing) compounds containing fluorine, chlorine, bromine, iodine, or astatine

HAZMAT team: hazardous materials response group

heavy metals: metallic elements with high atomic weights; (e.g. mercury, chromium, cadmium, arsenic, and lead); can damage living things at low concentrations and tend to accumulate in the food chain

hemoglobin: oxygen-carrying protein complex in red blood cells

herbicide: a chemical pesticide designed to control or destroy plants, weeds, or grasses

heterotrophic phytoplankton: floating microorganisms that consume other organisms for food

hexavalent: an oxidation state characterized by the ability to make six bonds; symbolized by (VI)

hormone receptors: cell proteins that respond to hormones to influence cell behavior

hormone: a molecule released by one cell to regulate development of another

host: in genetics, the organism, typically a bacterium, into which a gene from another organism is transplanted; in medicine, it is an animal infected or parasitized by another organism

humus: rich soil component derived from plant breakdown and bacterial action

hybridization: formation of a new individual from parents of different species or varieties

hydraulic: related to fluid flow

hydrocarbon: compounds of hydrogen and carbon

hydrodynamic condition: related to flow of water

hydrology: the science dealing with the properties, distribution, and circulation of water

hydromodification: any process that alters the hydrologic characteristics of a body of water

immobile: not moving

immunocompromised: having a weakened immune system

impact: a change to the environment resulting from a human activity or product

impermeable: not easily penetrated; the property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water

in situ: in its original place; unmoved or unexcavated; remaining at the site or in the subsurface

incident solar: sun energy that hits a particular spot

industrial metabolism: flow of resources and energy in an industrial system

inertness: inability to react chemically

infrastructure: the basic facilities, services, and installations needed for the functioning of a system, i.e., the various components of a water supply system

ingest: take in through the mouth

inhalation: drawing into the lungs by breathing

injection well: a well into which fluids are pumped for purposes such as underground waste disposal, improving the recovery of crude oil, or solution mining

inorganic: compounds not containing carbon

integrative commons governance: a governing system which recognizes and protects publicly shared resources, usually under local control

integrity: wholeness and stability

interest groups: corporate or citizen groups with a stake in influencing legislation

intergenerational sustainability: ability of a system to remain stable and productive over several generations

ion: an electrically charged atom or group of atoms

isotope: a variation of an element that has the same atomic number of protons but a different weight because of the number of neutrons; various isotopes of the same element may have different radioactive behaviors, some are highly unstable

labor market: the area or pool of workers from which an employer draws employees

lake acre: an acre of lake surface

land subsidence: sinking or settling of land

landfills: sanitary landfills are disposal sites for nonhazardous solid wastes spread in layers, compacted to the smallest practical volume, and covered by material applied at the end of each operating day; secure chemical landfills are disposal sites for hazardous waste, selected and designed to minimize the chance of release of hazardous substances into the environment

late-onset: occurring in adulthood or old age

leach pad: in mining: a specially prepared area where mineral ore (especially gold) is heaped for metal extraction

leach solution: in mining: chemical solution sprayed on ore to extract metal

leach: dissolve out

leachate: water that collects contaminants as it trickles through wastes, pesticides, or fertilizers; leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, ground water, or soil

leguminous: members of the pea family, or legumes

lipophilicity: solubility in or attraction to waxy, fatty, or oily substances

locomotion: self-powered movement

loess: soil deposited by wind

low tillage: reduced level of plowing

maceral: organic remains visible in coal

macroscopic: large enough to be visible, in contrast to microscopic

Magna Carta: English charter giving landowners rights under the king's authority

malleable: able to be shaped and bent

Malthusian hypothesis: idea that populations always grow faster than their food supply, from Thomas Malthus

maximum contaminant level: in water: the maximum permissible level of a contaminant in water delivered to any user of a public system; MCLs are enforceable standards

media: specific environments—air, water, soil—which are the subject of regulatory concern and activities

mediation: dispute resolution in which a neutral third party helps negotiate a settlement

megawatt: one million watts

mesothelioma: malignant tumor of the mesothelium, a cell layer within the lungs and other body cavities

metabolism: physical and chemical reactions within a cell or organism necessary for maintaining life

metabolite: any substance produced by biological processes, such as those from pesticides

metabolize: chemically transform within an organism

methanogenesis: creation of methane gas by microbes

microorganism: bacteria, archaea, and many protists; single-celled organisms too small to see with the naked eye

mine workings: the parts of a quarry or mine that is being excavated

mineralize: convert to a mineral substance

mitigation: measures taken to reduce adverse impacts

mixing zone: an area of a lake or river where pollutants from a point source discharge are mixed, usually by natural means, with cleaner water

mole: a chemical quantity, 6×10^{23} molecules. For oxygen, this amounts to 32 grams

molecule: the smallest division of a compound that still retains or exhibits all the properties of the substance

molluscicide: chemical that kills mollusks

monoculture: large-scale planting of a single crop species

multilateral treaty: treaty between more than two governments

multisite: several sites

mutagenic: capable of causing permanent, abnormal genetic change

natural attenuation: reduction in a pollutant through combined action of natural factors

nematocide: a chemical agent which is destructive to nematodes

nematode: worm-like organisms common in soil

neo-Malthusians: modern adherents to the ideas of Thomas Malthus

neonate: newborn

neural: related to nerve cells or the nervous system

neurodegeneration: loss of function and death of brain cells

neurology: medical science relating to the nervous system

neurotoxic: harmful to nerve cells

neurotoxicant: chemical that is toxic to neurons, or brain cells

nitrate catch crop: crop planted to harvest soil nitrates

nitrification: the process whereby ammonia, typically in wastewater, is oxidized to nitrite and then to nitrate by bacterial or chemical reactions

nonpoint source pollution: pollution originating from a broad area, such as agricultural runoff or automobile emissions

nucleotide: building block of DNA and RNA in a cell

off-gas control: control of gases released into the air

open path monitor: detection device that employs a beam of light passing through an open space

organic: referring to or derived from living organisms; in chemistry, any compound containing carbon

organochlorine: chemical containing carbon and chlorine

organophosphate: pesticide that contains phosphorus; short-lived, but some can be toxic when first applied

outfall: the place where effluent is discharged into receiving waters

overburden: rock and soil cleared away before mining

ovoid: shaped like an oval or egg

oxidize: react with oxygen

oxygenate: increase the concentration of oxygen within an area

ozonation: application of ozone to water for disinfection or for taste and odor control

PAHs: polyaromatic hydrocarbons; compounds of hydrogen and carbon containing multiple ring structures

particulate: fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions; they can also be very small solids suspended in water, gathered together by coagulation and flocculation

patent: legal document guaranteeing the right to profit from an invention or discovery

pathogenic: causing illness

pathway: the physical course a chemical or pollutant takes from its source to the exposed organism

PCBs: polychlorinated biphenyls; two-ringed compounds of hydrogen, carbon, and chlorine

per capita: per individual person in the population

percolating: moving of water downward and radially through subsurface soil layers, usually continuing downward to groundwater; can also involve upward movement of water

persistent bioaccumulative toxics: a group of substances that are not easily degraded, accumulate in organisms, and exhibit an acute or chronic toxicity

pH: an expression of the intensity of the basic or acid condition of a liquid; may range from 0 to 14, where 0 is the most acid, 7 is neutral, and 14 is most base; natural waters usually have a pH between 6.5 and 8.5

photochemical: light-induced chemical effects

phthalate: particular class of complex carbon compounds

physical removal: digging up and carting away

phytoplankton: that portion of the plankton community comprised of tiny plants; e.g. algae, diatoms

planktonic: that portion of the plankton community comprised of tiny plants; e.g. algae, diatoms

plume: a visible or measurable discharge of a contaminant from a given point of origin; can be visible, invisible, or thermal in water, or visible in the air as, for example, a plume of smoke

PM-10: airborne particles under 10 micrometers in diameter

polymer: a natural or synthetic chemical structure where two or more like molecules are joined to form a more complex molecular structure (e.g., polyethylene)

polyvinyl chloride (PVC): class of complex carbon compounds containing chlorine

pore waters: water present in the pores or cavities in sediments, soil, and rock

porosity: degree to which soil, gravel, sediment, or rock is permeated with pores or cavities through which water or air can move

priority pollutant: a designated set of common water pollutants

protein: complex nitrogenous organic compound of high molecular weight made of amino acids; essential for growth and repair of animal tissue; many, but not all, proteins are enzymes

protocol: in government: agreement establishing rules or code of conduct; science: a series of formal steps for conducting a test

pyrethroid: chemicals derived from chrysanthemums and related plants

radionuclide: radioactive particle, man-made or natural, with a distinct atomic weight number; can have a long life as soil or water pollutant

ratification: formal approval

raw water: intake water prior to any treatment or use

reactive chemicals: chemicals likely to undergo chemical reaction

recharge: the process by which water is added to a zone of saturation, usually by percolation from the soil surface (e.g., the recharge of an aquifer)

reclamation: in recycling: restoration of materials found in the waste stream to a beneficial use which may be for purposes other than the original use

reevaporate: return to the gaseous state

refractory: resistant (to heat: difficult to melt; also to authority)

refrigerant: liquid or gas used as a coolant in refrigeration

regenerative: able to be regenerated or created anew

remediate: reduce harmful effects; restore contaminated site

remediation: cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site or for the Asbestos Hazard Emergency Response program

residue: the dry solids remaining after evaporation

respiratory: having to do with breathing

river mile: one mile, as measured along a river's centerline

royalty: money paid by a user to an owner

scrubber: an air pollution control device that uses a spray of water or reactant or a dry process to trap pollutants in emissions

sedative: substance that reduces consciousness or anxiety

sediment impoverishment: loss of sediment

sedimentary: related to or formed by deposition of many small particles to form a solid layer

seep: movement of substance (often a pollutant) from a source into surrounding areas

septic tank: an underground holding tank for wastes from homes not connected to a sewer line

sick building syndrome: shared health and/or comfort effects apparently related to occupation of a particular building

sink: hole or depression where a compound or material collects; thermodynamics: part of a system used to collect or remove heat

smelting: the process in which a facility melts or fuses ore, often with an accompanying chemical change, to separate its metal content; emissions cause pollution

solubility: the amount of mass of a compound that will dissolve in a unit volume of solution; aqueous solubility is the maximum concentration of a chemical that will dissolve in pure water at a reference temperature

soluble: able to be dissolved in

solvent: substance, usually liquid, that can dissolve other substances

sorbent: a substance that absorbs (within) or adsorbs (on the surface) another substance

source reduction: reducing the amount of materials entering the waste stream from a specific source by redesigning products or patterns of production or consumption (e.g., using returnable beverage containers); synonymous with waste reduction

spatial: related to arrangement in space

spent radioactive fuel: radioactive fuel rods after they has been used for power generation

spray dryers: dryer used to remove heavy metals and other pollutants from incineration gases

standing: the legal right to pursue a claim in court

stenothermic: living or growing within a narrow temperature range

stewardship: care for a living system

stratosphere: the portion of the atmosphere ten to twenty-five miles above the earth's surface

subset: a smaller group within a larger one

subsidence: sinking of earth surface due to underground collapse

substrate: surface on which an organism, i.e. mold, grows

Superfund: the fund established to pay for the cleanup of contaminated sites whose owners are bankrupt or cannot be identified

supersonic: faster than the speed of sound

suppression: reduction in or prevention of an effect

surface water: all water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, seas, estuaries, etc.)

sustainable development: economic development that does not rely on degrading the environment

sustainable: able to be practiced for many generations without loss of productivity or degradation of the environment

synergistic: combination of effects greater than the sum of the parts

systemic: throughout the body

tailings: residue of raw material or waste separated out during the processing of mineral ores

Takings impacts analysis: analysis of the impacts due to government restriction on land use

teach-in: educational forum springing from a protest movement (derived from sit-in protests)

temperature inversion: temporary trapping of lower warm air by higher cold air

teratogen: something that causes birth defects, may be radiation, a chemical or a virus

teratogenic: causing birth defects

thermal infrared imaging: photographs in which contrast depends on differences in temperature

thermal shock: rapid temperature change beyond an organism's ability to adapt

thermodynamic limitations: tendency of chemical reactions to reverse when products remain in the reaction mixture

thermotolerance: ability to withstand temperature change

titleholder: the person or entity holding the legal title or deed to a property

toluene: carbon-containing chemical used in fuel and as a solvent

topography: the physical features of a surface area including relative elevations and the position of natural and man-made (anthropogenic) features

transient: present for a short time

transuranic waste: waste containing one or more radioactive elements heavier than uranium, created in nuclear power plants or processing facilities

tribunal: committee or board appointed to hear and settle an issue

trophic: related to feeding

turbid: containing suspended particles

turbine: machine that uses a moving fluid (liquid or gas) to gas to turn a rotor, creating mechanical energy

ultraviolet radiation: high-energy, short-wavelength light beyond human vision

unitary system: a centralized system or government

unreactivity: lack of chemical reactivity

unsaturated: capable of dissolving more solute, i.e., water

variable vale control: a system for automatically adjusting engine valve timing for better fuel efficiency

vector: an organism, often an insect or rodent, that carries disease; plasmids, viruses, or bacteria used to transport genes into a host cell: a gene is placed in the vector; the vector then "infects" the bacterium

volatility: relating to any substance that evaporates readily

volatilize: vaporize; become gaseous

Warsaw Pact: nations allied with the former Soviet Union

waste-to-energy: to convert solid waste into a usable form of energy

water table: the level of water in the soil

watershed: the land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds

wetland: an area that is saturated by surface or ground water with vegetation adapted for life under those soil conditions, as swamps, bogs, fens, marshes, and estuaries

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